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STANDARD TEST CASE RUNS FOR THE EMPULSE
MONOPOLE FIELDSOLVER AND CONDUCTIVITY
GENERATION MODEL

Frank W. Chambers
David M. Cox

March 2, 1981

Lawrence
Livermore
Laboratory

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(12) 60

Abstract

The physical models for the conductivity generation and fieldsolver used in several LLNL beam propagation codes are presented. A generalized beam profile is presented and four standard test cases are proposed.

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(15)

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NOTE

This report was originally prepared and distributed informally in March, 1981. Since that time there have been sufficient referals to the test cases to indicate the need for a formal reference.

This UCID contains the original text and revised output from the test cases. Several changes were made in the output format. The X development of the test cases was followed only for 100 cm. Plots versus X are now on a logarithmic scale to facilitate extraction of small X results. Snapshot output is now presented at 1.0, 10.0, 20.0, 50.0, and 100.0 cm. in X.

The results for test case B as originally distributed were in error as pointed out by Dr. Keith Brueckner. The X step employed was too large to properly describe the avalanche ionization. Hence, in this report all cases have been run with reduced X steps.

Frank Chambers

September, 1981

I. Introduction

At the high current beam propagation workshop (Ref. 1) it was realized that fieldsolver comparisons between working groups should be made for beams with expanded heads such as develop by blowoff and erosion during propagation. To facilitate comparisons of the fieldsolvers while removing the differences due to evolution of the beam during propagation, standard test cases with imposed beam head profiles ~~have been~~ suggested. Hence, unambiguous field and conductivity generation calculation comparisons can be made.

The field equations solved for this report are derived elsewhere (Ref. 2). The plasma generation model includes a direct deposition term, an avalanche ionization term based on experimental data (Ref. 3), and a recombination term. Plasma density is related to a scalar conductivity through the momentum transfer collision frequency. These models have been used by the Beam Research Group at LLNL in the EMPULSE I (Ref. 4), EMPULSE II (Ref. 5), RINGBEARER I (Ref. 6), and RINGBEARER II (Ref. 7) codes. The actual coded fieldsolver used for the results in this report was extracted from the EMPULSE II code. The code PHOENIX was constructed to run this fieldsolver and generate the appropriate diagnostic output.

Standard test cases are proposed where the beam current density is prescribed at all points in space. This is accomplished using a simple parameterized profile which can represent a cylindrical beam or one with an eroded nose. Four test cases are proposed; PHOENIX results for these cases are presented. In this report almost all quantities are in cgs units; beam "temporal" parameters such as rise time (length) are always given in centimeters.

II. Modelling

Coordinate System – Z, X, r, θ:

Z – distance of propagation of a beam segment – since beams are not propagated in the test cases Z = 0.

X – distance back from the beam head.

r, θ – transverse coordinates in the cylindrical geometry – since only monopole fields are calculated all quantities are θ independent.

Field Equations:

$$\frac{1}{r}\frac{\partial}{\partial r} r \frac{\partial}{\partial r}(\mathcal{A}+\varphi) = -\frac{4\pi}{c}\left(J_{BZ}-\sigma\frac{\partial\mathcal{A}}{\partial X}\right) \tag{1}$$

$$\frac{1}{r}\frac{\partial}{\partial r} r \frac{\partial^2\mathcal{A}}{\partial r\partial X} = \frac{1}{r}\frac{\partial}{\partial r} r \frac{4\pi\sigma}{c}\frac{\partial\varphi}{\partial r} \tag{2}$$

Boundary Conditions:

$$\frac{\partial\mathcal{A}}{\partial r}(r=0) = \frac{\partial\varphi}{\partial r}(r=0) = 0 \tag{3}$$

$$\mathcal{A}(r=b) = \varphi(r=b) = 0 \tag{4}$$

$\mathcal{A}$ and φ are the usual monopole field potentials, σ is the plasma conductivity, and J_{BZ} is the Z directed component of the beam current. The parameter b is the radius at which there is assumed to be a metal wall. A term of the form $(\partial^2\mathcal{A}/\partial X^2)$ has been dropped in equation (1), except in the RINGBEARER I code where this term is retained. The RINGBEARER I code uses a field equation obtained by combining equations (1) and (2) and using r^2 as the independent variable in the radial direction. In this case the boundary condition on $\mathcal{A}$ at $r = 0$ is modified (Ref. 6).

<u>Conductivity Calculation:</u>

The simplified air chemistry models and optional features originated by E. Lee (Ref. 4,5) are described in the following section. Several minor changes have been made in the recombination and collision frequency models to allow the extraction of a single electron temperature parameter and to simplify the analytic forms. These changes will not affect computed conductivities. The field dependent recombination and collision frequency models are included for completeness since they have been used in the past. However, current understanding of the air chemistry indicates better models are needed which retain the simplicity and utility of these models but with increased accuracy. Hence, we are <u>not</u> advocating the use of these models. In the standard cases reported herein recombination is omitted and the high electron temperature limit of the collision frequency is used.

The generation of electron density, n_e, is given by:

$$\frac{\partial n_e}{\partial X} = K' J_{BZ} + \frac{\nu_i}{c} n_e - \frac{\alpha}{c} n_e^2 \qquad (5)$$

where:

$$K' = \frac{(dE/dX)\ \rho}{\Delta E\ ec} \qquad (6)$$

Here $e = 4.803\ 10^{-10}$ esu and $c = 2.9979\ 10^{10}$ cm/s. Typically,

$$dE/dX = 2.52 \text{ MeV cm}^2/\text{gm} \qquad (7)$$

$$\rho = 1.29\ 10^{-3} \text{ gm/cm}^3 \quad (\text{air; } p = 760 \text{ torr, } T = 0°C) \qquad (8)$$

$$\Delta E = 33.73 \text{ eV/ion pair} \qquad (9)$$

The value of K′ used in these runs is:

$$K' = 6.69 \qquad (10)$$

To compute avalanche ionization, ν_i, a fit to experimental data (Ref. 3) is used:

$$\nu_i(s^{-1}) = \frac{A\ \tilde{\rho}\ S^3}{1 + B\ S + C\ S^2 + D\ S^3} \qquad (11)$$

$A = 1.423\ 10^{-4}$

$B = 9.179\ 10^{-6}$

$C = 2.656\ 10^{-10}$

$D = 2.820\ 10^{-17}$

$$S = \frac{E^2}{\bar{\rho}^2} \tag{12}$$

where E is the magnitude of the electric field in statvolts/cm and $\bar{\rho}$ is the gas density normalized to that at 273°K and one atmosphere.

For the computation of the recombination rate, α, and the momentum transfer collision frequency, ν_m, an electron temperature, T_e, is calculated from $E/\bar{\rho}$. Temperature is assumed to vary linearly with $E^2/\bar{\rho}^2$ due to ohmic dissapation; when $E = 0$ the electron temperature is the gas temperature.

$$T_e(eV) = T_g(eV) + \kappa\ (E^2/\bar{\rho}^2) \tag{13}$$

The value of κ is determined in slightly different manners for the recombination and collision frequency calculations. The intent in computing T_e is as a parameter for computing $\nu_m(E/\bar{\rho})$ and $\alpha(E/\bar{\rho})$; and T_e is not intended to accurately indicate the electron temperature for all $E/\bar{\rho}$. Since the formula for ν_m asymptotes above $T_e \sim 2$ eV and above this temperature α is quite small equation (13) is an adequate approximation.

Recombination, when included, is a function of $E/\bar{\rho}$:

$$\alpha(cm^3/s) = \frac{2.10\ 10^{-7}}{(T_e(eV)/.02586)^{.7}} = \frac{2.10\ 10^{-7}}{(T_e(°K)/300.)^{.7}} \tag{14}$$

$$\kappa = 4.6774\ 10^{-3}$$

This value of κ was determined by requiring that $T_e = 2/3$ eV when $T_g = .02586$ and $E^2/\bar{\rho}^2 = 137.0$. This recombination rate is due to the presence of O_2^+ and was suggested by Bob Johnston (Ref. 8). For the

standard case results thus far computed recombination has been omitted.

Assuming a scalar conductivity, σ is related to n_e by:

$$\sigma = \frac{n_e e^2}{m\nu_m} \qquad (15)$$

$m = 9.11\ 10^{-28}$ grams is the electron mass; ν_m is the momentum transfer collision frequency:

The momentum transfer collision frequency is modelled as a function of $E/\bar{\rho}$ as:

$$\nu_m(s^{-1}) = 4.86\ 10^{12}\ \bar{\rho}\ \frac{A + T_e}{B + T_e} \qquad (16)$$

$$\kappa = 4.8662\ 10^{-3}$$

$$A = 2.35835\ 10^{-3}$$

$$B = .561026$$

This value of κ was determined by requiring $T_e = 2/3$ eV when $T_g = 0$ and $E^2/\bar{\rho}^2 = 137.0$. This formula was determined by requiring agreement with tables (Ref. 9) at $T_e = .0235$ eV, 2/3 eV, and as $T_e \to \infty$. In the standard case results the high temperature limit ($T_e > 2$ eV) was used; namely,

$$\nu_m(s^{-1}) = 4.86\ 10^{12}\ \bar{\rho} \qquad (17)$$

When recombination is ignored and ν_m is constant $n_e \sim \sigma$ and the conductivity can be calculated directly using:

$$\frac{\partial\sigma}{\partial X} = KJ_B + \frac{\nu_i}{c}\sigma \qquad (17)$$

In this case for the previously given K′ value:

$$K = 3.48\ 10^{-4} \qquad (18)$$

Plots of ν_i, ν_m, and α versus E with $\bar{\rho} = 1.0$ are given in figures 1,2,3, and 4.

III. Standard Case Definitions, Parameters, and Output

Beam Profile:

$$I_B(X) = I_{B0} \tanh(X/L_R)$$

I_{B0} – Beam current at $X = \infty$
L_R – rise length in centimeters

$$J_B(r,X) = \bar{J}_B(r/R(X))\ I_B(X)/(\pi R^2(X))$$

$$R(X) = \mathrm{ROMIN} + (\mathrm{ROMAX}-\mathrm{ROMIN})/2.0\ (1-\tanh((X-\mathrm{XLOC})/\mathrm{XWDTH})$$

ROMIN – Beam radius as $X \to \infty$
ROMAX – Beam radius as $X \to -\infty$
XLOC – Location of "midpoint" of neck
XWDTH – Width of neck region

Gaussian – $\bar{J}(r/R) = e^{-r^2/R^2}$
Bennett – $\bar{J}(r/R) = 1/(1+r^2/R^2)^2$

Gas: 760 torr (1 atm) air and 76 torr (.1 atm) air
ν_m constant
$\alpha = 0$

Numerical:

XMAX = 200.0 cm.

Output:

Snapshot profiles in r of:

J_B, J_{NET}, $-J_{RET}$; σ; ν_i; c/ν_i;
$\mathcal{A}$; φ; E_R; E_Z

at: X = 10., 20., 40., 100., 200. cm.

History profiles in X of:

I_B; R_X; I_B, I_{NET}, I_{RET}, I_{EFF}; $E_Z(r=0)$; $\sigma(r=0)$; $\nu_i(r=0)$

Contour plots in X,r of:

$\mathcal{A}(X,r)$; $\nu_i(X,r)$

IV. Standard Cases

A. 10 kA, Standard Case
A 10 kA Bennett beam into full atmosphere at injection - beam is cylindrical with no eroded head.

I_{BO}	= 10000.0 A	ROMIN	= .5 cm
L_{RISE}	= 10.0 cm	ROMAX	= .5 cm
γ	= 100.0	XLOC	= 15.0 cm
p	= 760 torr	XWDTH	= 15.0 cm

B. 10 kA, Reduced Pressure
A 10 kA Bennett beam into one tenth atmosphere; at injection - beam is cylindrical with no eroded head.

I_{BO}	= 10000.0 A	ROMIN	= .5 cm
L_{RISE}	= 10.0 cm	ROMAX	= .5 cm
γ	= 100.0	XLOC	= 15.0 cm
p	= 76 torr	XWDTH	= 15.0 cm

C. 100 kA, Broad Nose
A 100 kA Bennett beam with an imposed eroded head but with a broad nose.

I_{BO}	= 100000.0 A	ROMIN	= .2 cm
L_{RISE}	= 30.0 cm	ROMAX	= 40.0 cm
γ	= 100.0	XLOC	= 15.0 cm
p	= 760 torr	XWDTH	= 15.0 cm

D. 100 kA, Narrow Nose
A 100 kA Bennett beam with an eroded head with radius parameters fitted to an SAI run.

I_{BO}	= 100000.0 A	ROMIN	= .5 cm
L_{RISE}	= 30.0 cm	ROMAX	= 100.0 cm
γ	= 100.0	XLOC	= 20.0 cm
p	= 760 torr	XWDTH	= 1.8 cm

V. PHOENIX Output

Frame 1. Input parameters are defined as follows:

```
C-
C-    NAMELIST INPUT FOR THE PHOENIX FIELDSOLVER
C-
C-    NAME         UNITS       DEFAULT       COMMENTS
C-
C-    BEAM PHYSICAL PARAMETERS
C-
C-    IBO          AMPS        10000..0      BEAM CURRENT
C-    LR           CM          30.0          BEAM RISE LENGTH
C-    GAMMAO                   100.0         BEAM ENERGY PARAMETER
C-    IPROFILE                 1             =1 FOR GAUSSIAN PROFILE
C-                                           =2 FOR BENNETT PROFILE
C-    ROMIN        CM          .5            MINIMUM RADIUS AT LARGE X
C-    ROMAX        CM          40.0          MAXIMUM RADIUS AT LARGE -X
C-    XLOC         CM          15.0          LOCATION OF NECK REGION
C-    XWDTH        CM          15.0          WIDTH OF NECK REGION
C-
C-    GAS PARAMETERS
C-
C-    ENOO         CM**-3      1.E4          INITIAL ELECTRON DENSITY
C-    KSCATTER                 1.699157E3    SCATTERING PARAMETER
C-                                           4(E**2/MC**2)(CN/MC**3)
C-    KBEAM                    6.69          DIRECT DEPOSITION PARAMETER
C-                                           (DE/DX)*ROE/(DELTAE*E*C)
C-    LAMBDARO     CM          3.13336E4     RADIATION LENGTH
C-    IFROHAT                  1             -1 FOR NO CHANNEL
C-    RHOHATO                  1.00          DENSITY, VARY TO VARY PRESSURE
C-
C-    R GRID
C-
C-    NR                       NRMX          NUMBER OF R GRID POINTS
C-    B            CM          10.0          MAXIMUM RADIUS FOR FIELDS
C-    NRLNSTEP                 40            =0 PURELY EXPONENTIAL R GRID
C-                                           =NR-1  LINEAR GRID
C-                                           >1, < NR-1; HYBRID GRID
C-    RO                       1.0           ORIGINAL BEAM RADIUS
C-    RLNFAC                   1.0           FRACTION OF RO TO BE LINEAR
C-
C-    X GRID
C-
C-    NX                       NXMX          NUMBER OF X GRID POINTS
C-    NDX                      1             NUMBER OF DIFFERENT SIZE STEPS
C-    DXVALUES     CM          .2            ARRAY OF X STEP SIZES
C-    XLIMITS                                ARRAY OF SWITCHING PLACES
C-
```

Frames 2–11. Snapshots versus r at several X.

Current densities are J_B, $J_{RET}=\sigma E_Z$, and $J_{NET}=J_B+J_{RET}$. Since usually $J_{RET}<0$, $-J_{RET}$ is plotted.

c/ν_i is plotted to indicate the efolding distance in centimeters for the computed avalanche ionization rate.

Frames 12,13 Prescribed beam current and radius profiles.

Frame 14 Neutralization fractions, the plotted quantities are:

"B" -> $I_B(X)/I_{B0}$

"R" -> $-I_{RET}/I_{B0} = \int_0^b -\sigma E_Z \, 2\pi r dr/I_{B0}$

"N" -> $(I_B+I_{RET})/I_{B0} = I_{NET}/I_{B0}$

"U" -> $I_{EFF}/I_{B0} = (\frac{I_A}{I_B}) \int_0^b \frac{er}{\gamma mc^2} \frac{\partial \mathcal{A}}{\partial r} \frac{2\pi r dr \; J_B}{I_B}$

I_{EFF} is the effective current providing the beam pinch force; if, in the magnetic regime, $I_{RET} = 0$ (and $J_{RET}=0$) then $I_{EFF} = I_B$; if J_{RET} has the identical profile to J_B then $I_{EFF} = I_{NET}$.

Frames 15,16,17. X histories of the on-axis (r=0) values of E_Z, σ, and ν_i.

Frame 18. Contour plot of $\mathcal{A}(X,r)$, contours are at .1–.9 $\mathcal{A}_{max}$.

Frame 19. Contour plot of $\nu_i(X,r)$, contours logarithmically spaced.

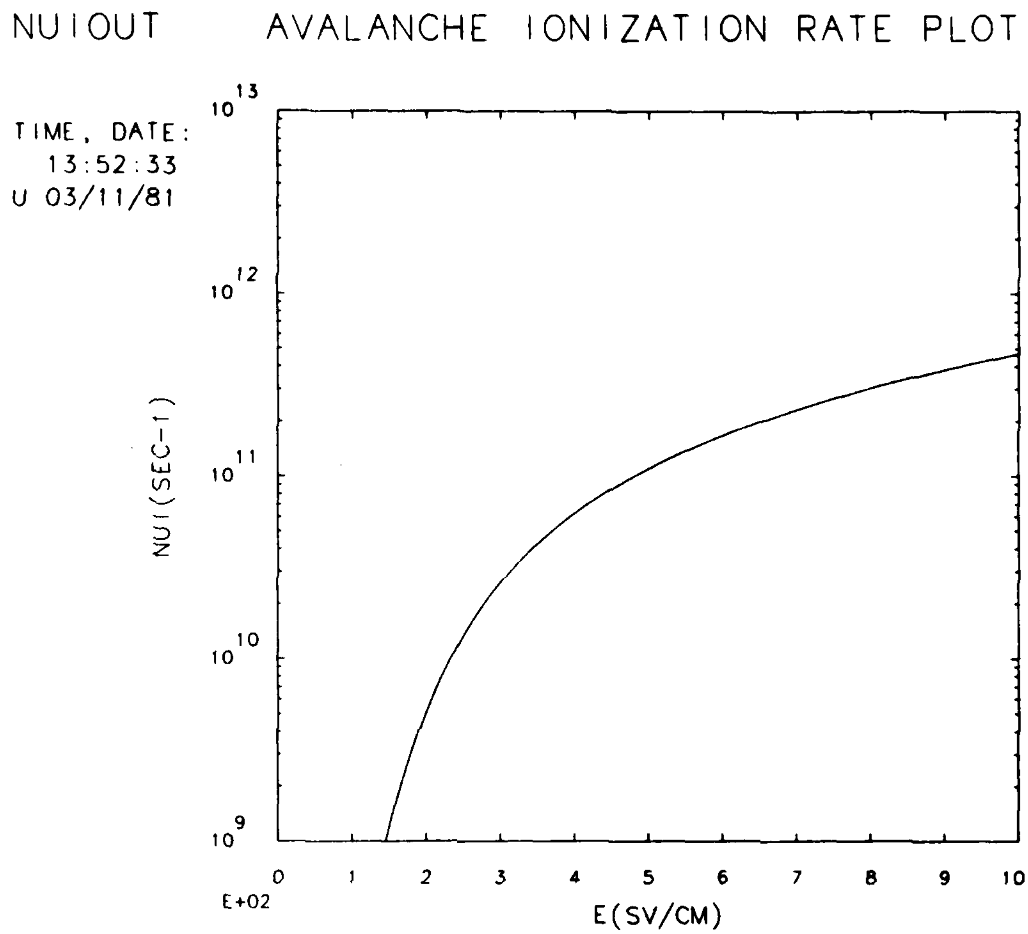

Figure 1. Plot of the avalanche ionization rate, ν_I, versus E with $\bar{\rho}$ = 1.0. E is varied from 0 to 1000 statvolts/cm.

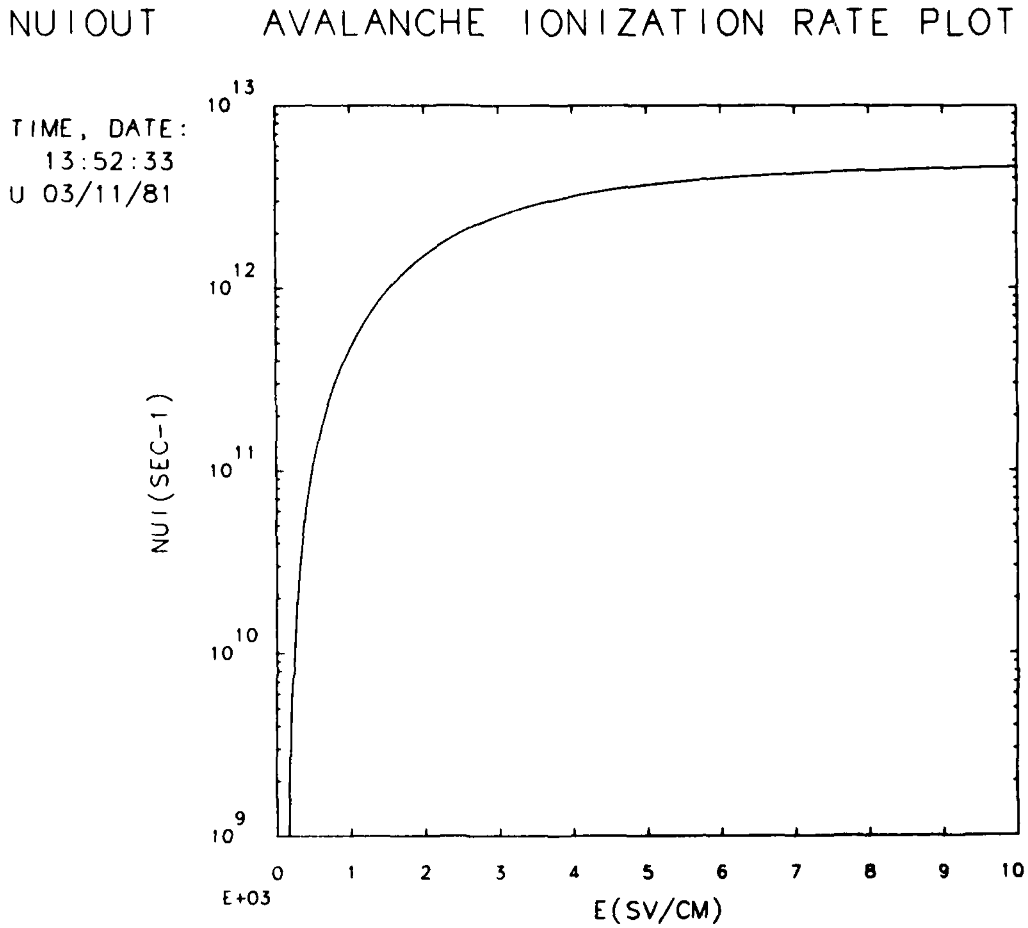

Figure 2. Plot of the avalanche ionization rate, ν_i, versus E with $\bar{\rho}$ = 1.0. E is varied from 0 to 10000 statvolts/cm. Note that ν_i is reaching the asymptotic value, $\nu_i = 5.05\ 10^{12}$.

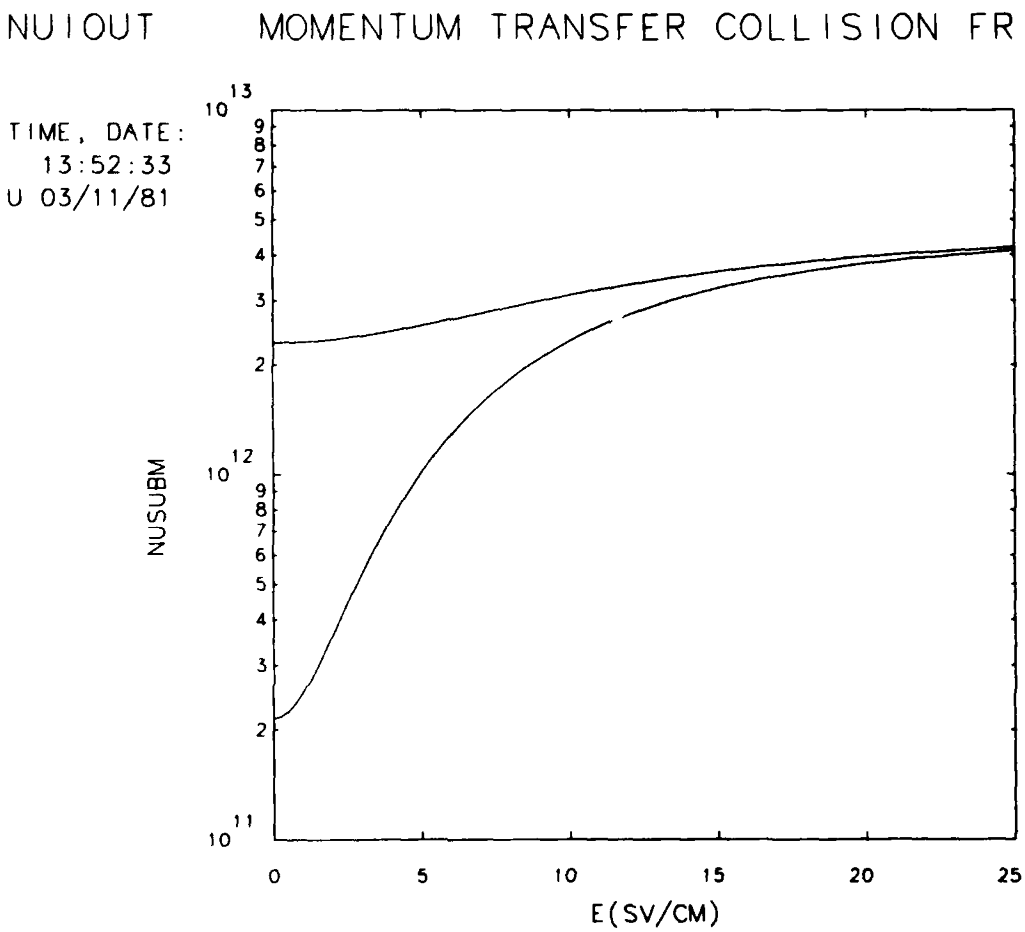

Figure 3. Plot of the momentum transfer collision frequency, ν_m, versus E with $\bar{\rho} = 1.0$. The lower trace is with $T_g = .0235$ eV, the upper trace is with $T_g = .5$ eV.

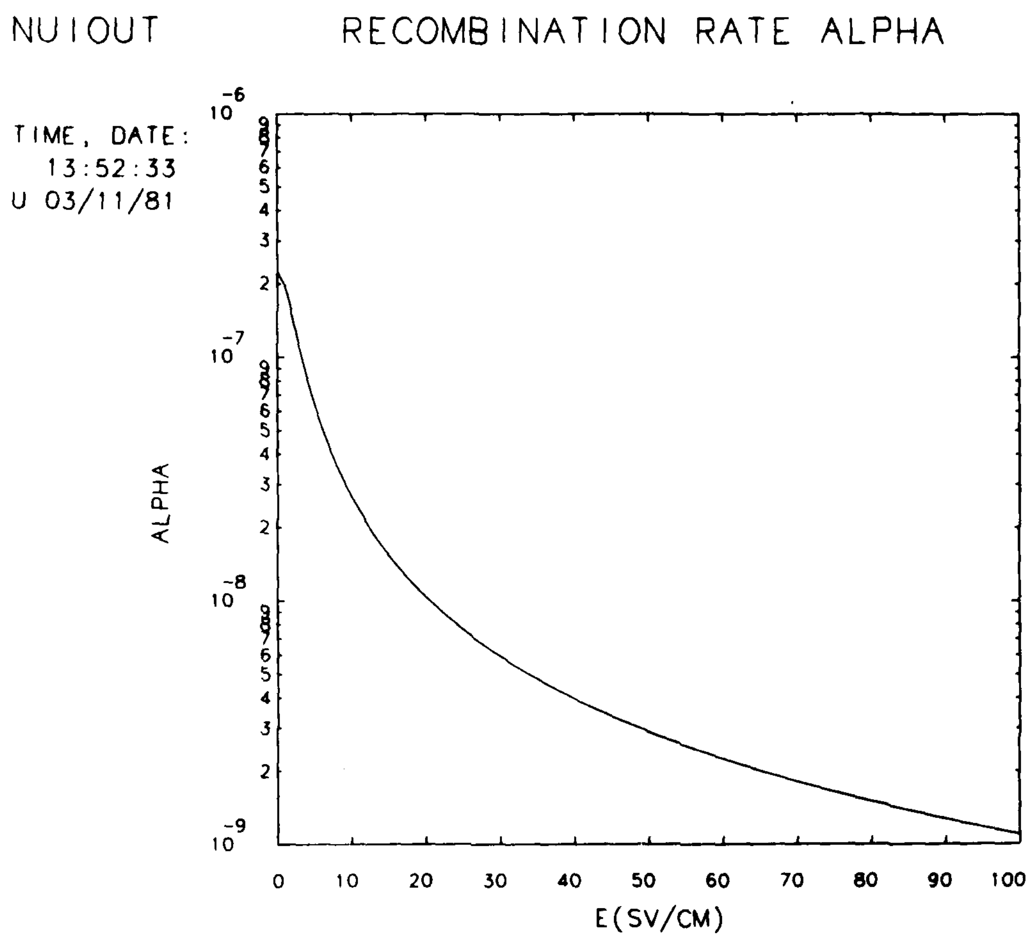

Figure 4. Plot of recombination rate, α, versus $E/\bar{\rho}$. E field values given on the horizontal axis are for $\bar{\rho} = 1.0$.

REFERENCES

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9. S. C. Brown Basic Data of Plasma Physics The MIT Press, Cambridge, Ma. 1967.

VERSION RB9MEMO8

ENDTEXT

PHOENIX

BEAM PARAMETERS

IBO(AMPS)	=	1.000E+04	LR(CM)	=	1.000E+01
GAMMAO	=	1.000E+02	IPROFILE	=	2
ROMIN(CM)	=	5.000E-01	ROMAX(CM)	=	5.000E-01
XLOC(CM)	=	1.500E+01	XWDTH(CM)	=	1.500E+01
ISIGMOD	=	0			

GAS PARAMETERS

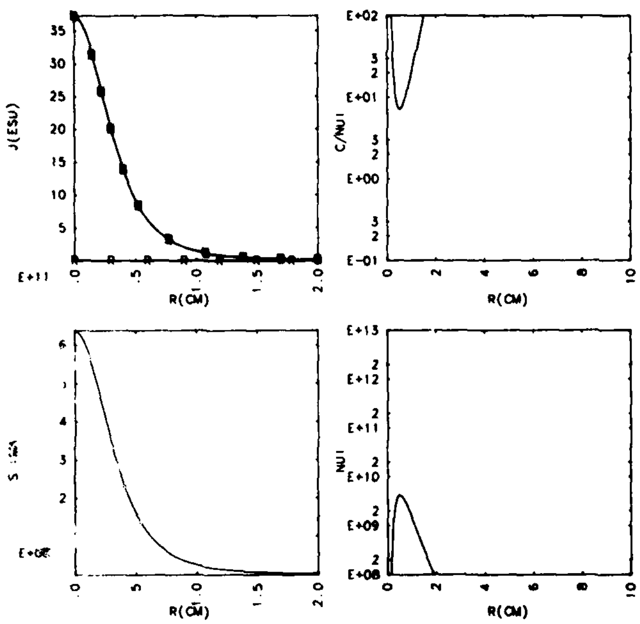
ENOO(CM**-3)	=	1.000E+04	KSCATTER	=	1.699E+03
KBEAM	=	6.690E+00	LAMBDARO	=	3.133E+04
IFRHOHAT	=	1	RHOHATO	=	1.000E+00

NUMERICAL PARAMETERS

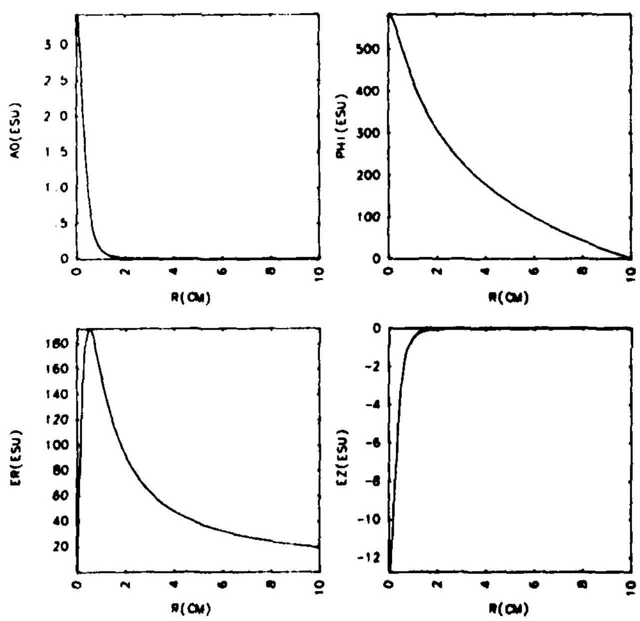
NR	=	220	B(CM)	=	1.000E+01
NRLNSTEP	=	40	RO(CM)	=	1.000E+00
RINFAC	=	1.000E+00	NX	=	2500
NDX	=	1	DXVALUES(1) CM	=	4.000E-02

CASE: A FRAME: 1

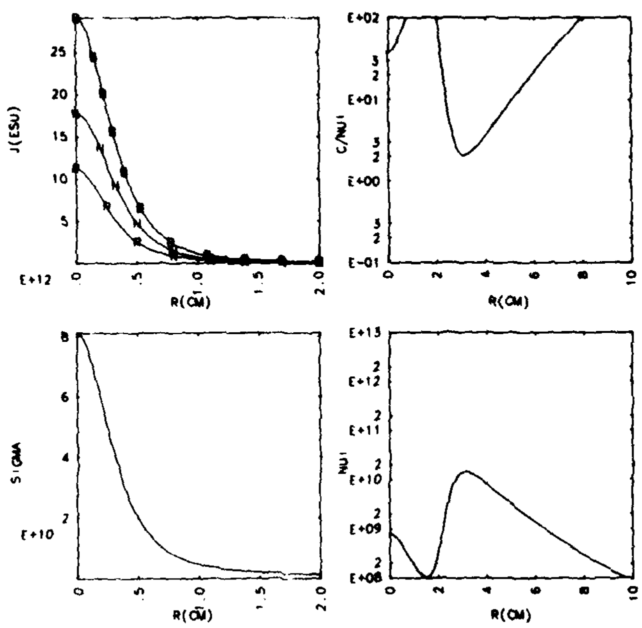
SNAPSHOT: X = 1.00, X STEP NO. 25 CASE: A FRAME: 2



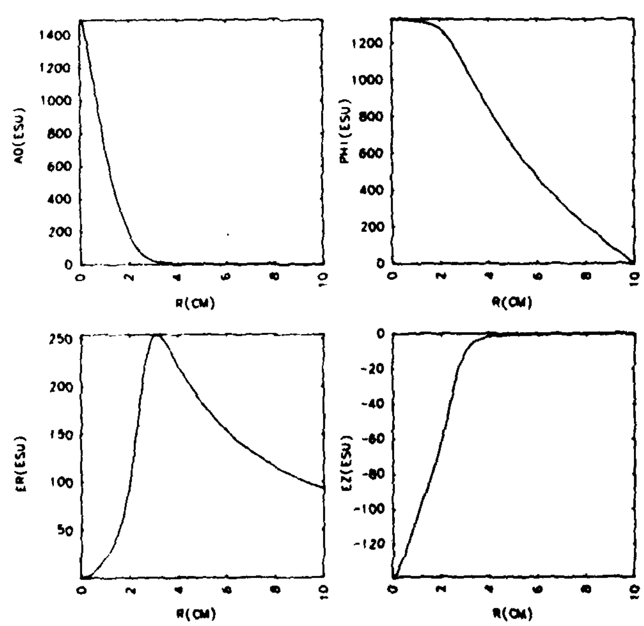
SNAPSHOT: X = 1.00, X STEP NO 25 CASE: A FRAME: 3



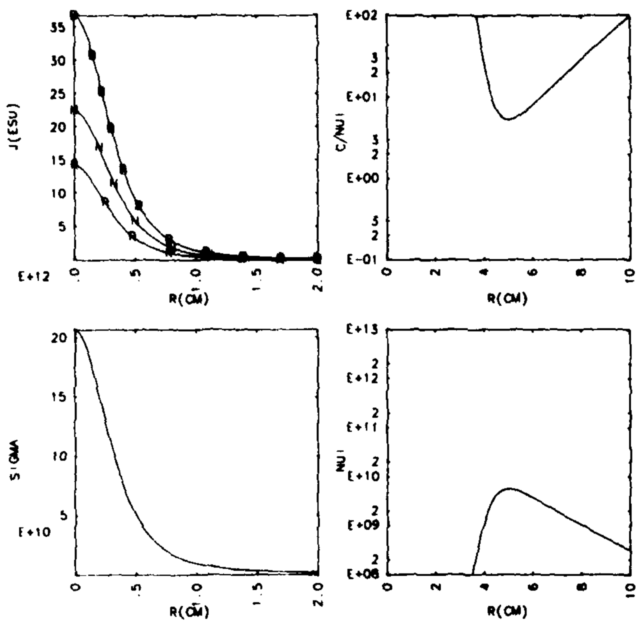
SNAPSHOT X = 10.00, X STEP NO. 250   CASE: A FRAME: 4



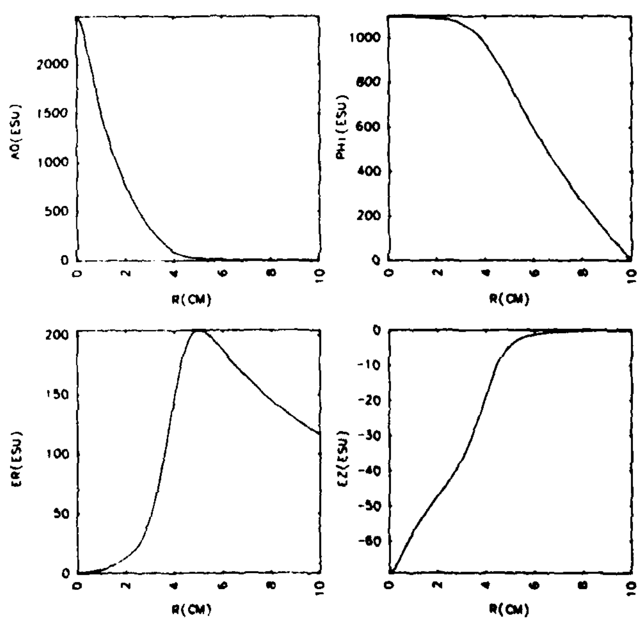
SNAPSHOT X = 10.00, X STEP NO. 250   CASE: A FRAME: 5



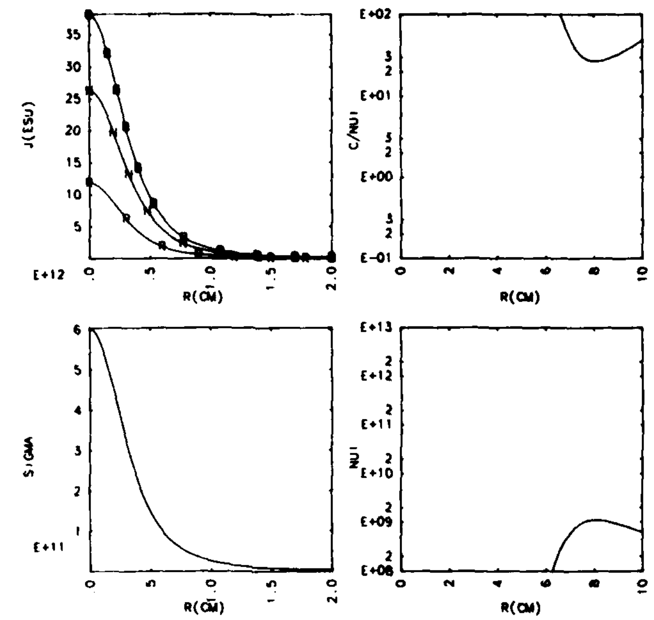
SNAPSHOT: x = 20.00, x STEP NO. 500 CASE: A FRAME: 6



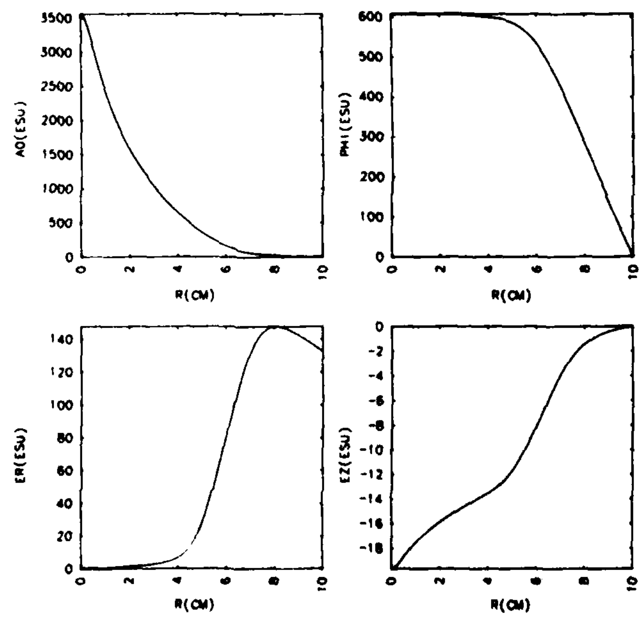
SNAPSHOT: x = 20.00, x STEP NO. 500 CASE: A FRAME: 7



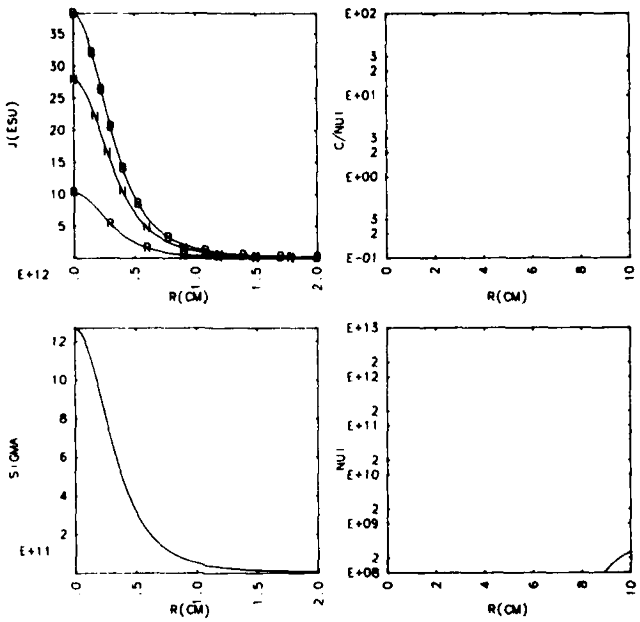
SNAPSHOT: X = 50.00, X STEP NO. 1250 CASE: A FRAME: 8



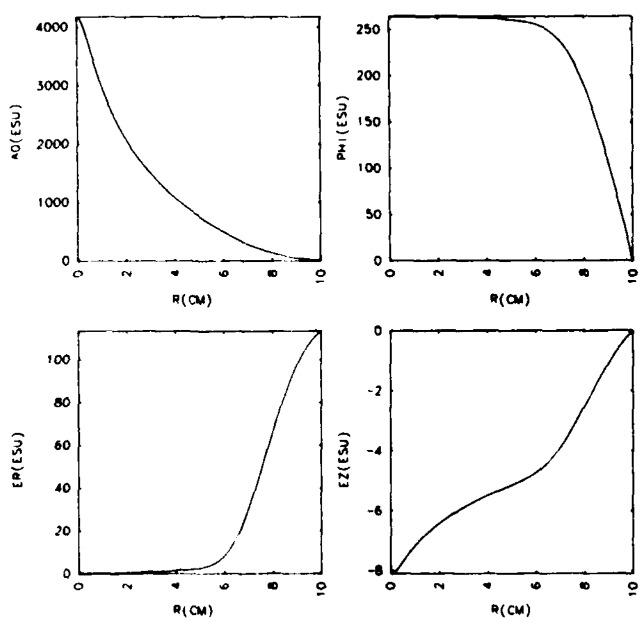
SNAPSHOT: X = 50.00, X STEP NO. 1250 CASE: A FRAME: 9



SNAPSHOT: X = 100.00, X STEP NO. 2500 CASE: A FRAME: 10



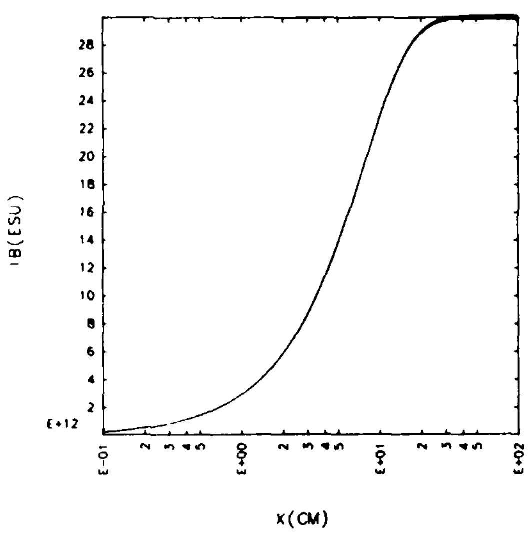
SNAPSHOT: X = 100.00, X STEP NO. 2500 CASE: A FRAME: 11



PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:36:58
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

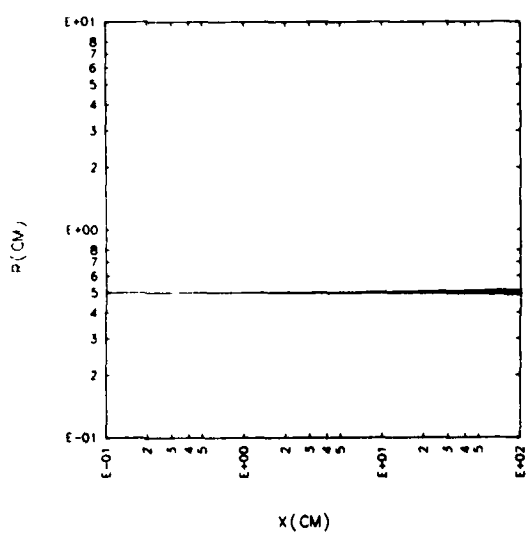


CASE A FRAME 12

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:36:58
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

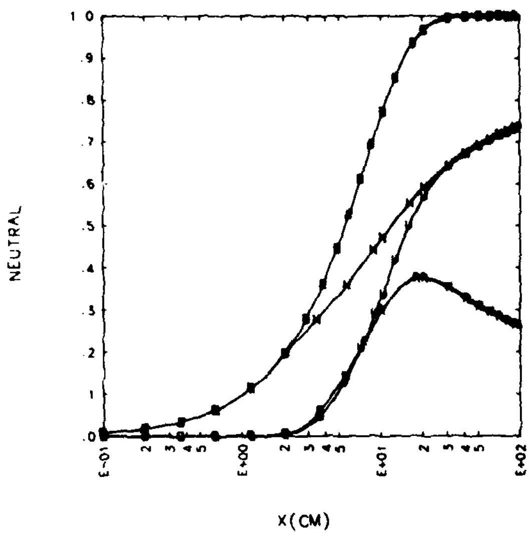


CASE A FRAME 13

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:36:58
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

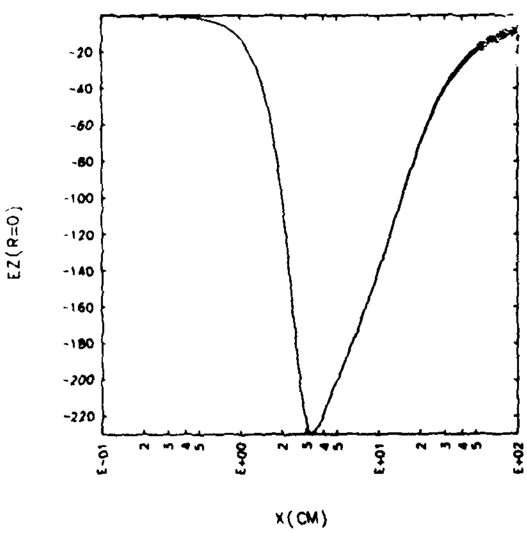


CASE: A FRAME: 14

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:36:58
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

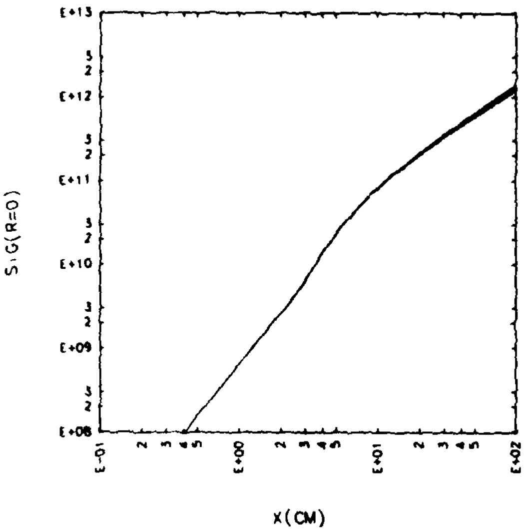


CASE A FRAME 15

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:36:58
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

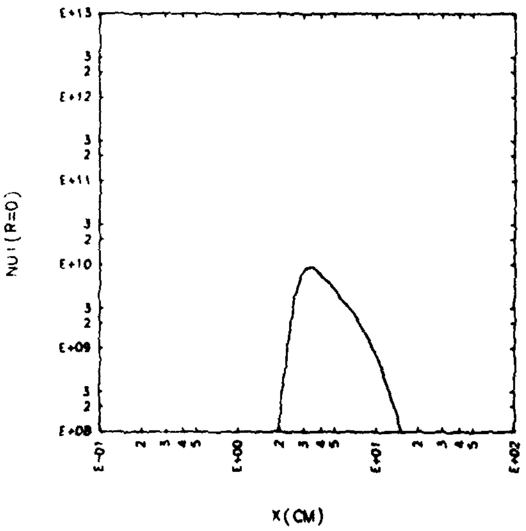


CASE: A FRAME: 16

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:36:58
09/22/81

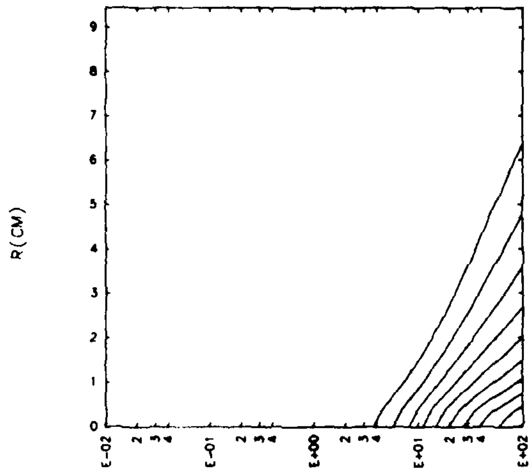
IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01



CASE: A FRAME: 17

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF AO(R,X)

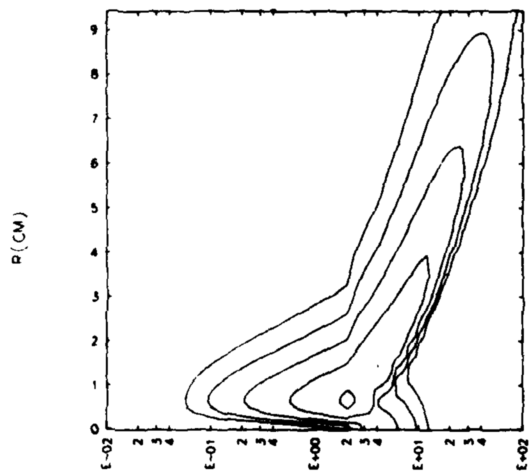
TIME, DATE
13:36:58
09/22/81



CASE A FRAME 18

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF NUSUBI(R,X)

TIME, DATE
13:36:58
09/22/81



CASE A FRAME 19

PHOENIX

BEAM PARAMETERS

IBO(AMPS)	= 1.000E+04	LR(CM)	= 1.000E+01
GAMMAO	= 1.000E+02	IPROFILE	= 2
ROMIN(CM)	= 5.000E-01	ROMAX(CM)	= 5.000E-01
XLOC(CM)	= 1.500E+01	XWDTH(CM)	= 1.500E+01
ISIGMOD	= 0		

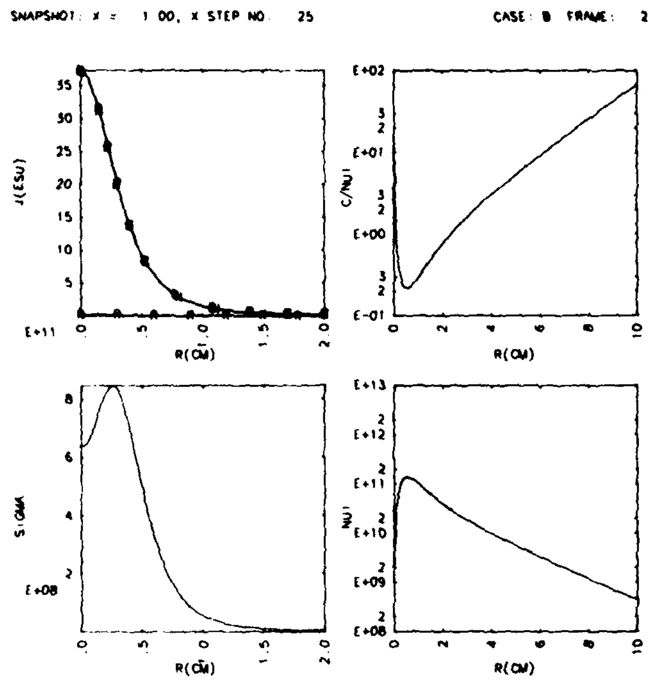
GAS PARAMETERS

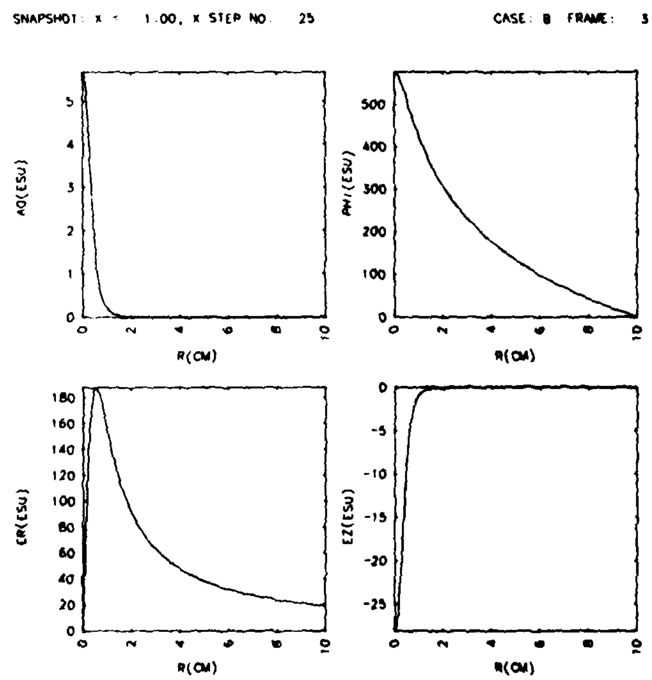
ENOO(CM**-3)	= 1.000E+04	KSCATTER	= 1.699E+03
KBEAM	= 6.690E+00	LAMBDARO	= 3.133E+04
IFRHOHAT	= 1	RHOHATO	= 1.000E-01

NUMERICAL PARAMETERS

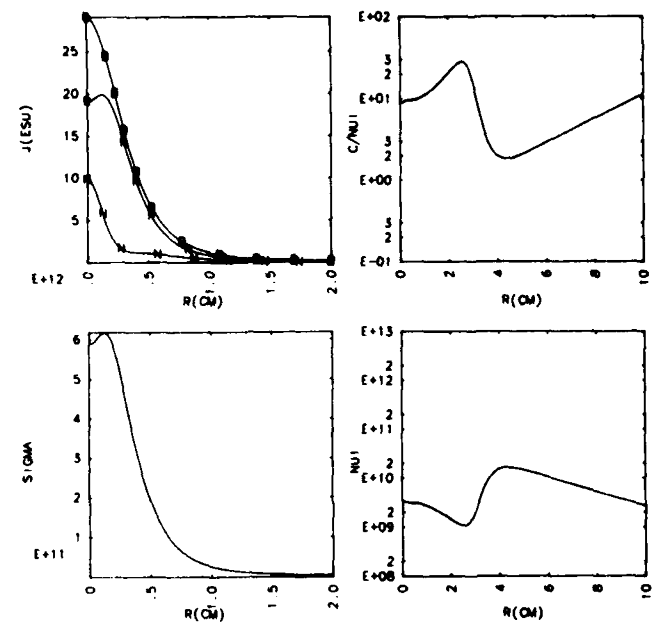
NR	= 220	B(CM)	= 1.000E+01
NRLNSTEP	= 40	RO(CM)	= 1.000E+00
RLNFAC	= 1.000E+00	NX	= 2500
NDX	= 1	DXVALUES(1) CM=	4.000E-02

CASE: B FRAME: 1

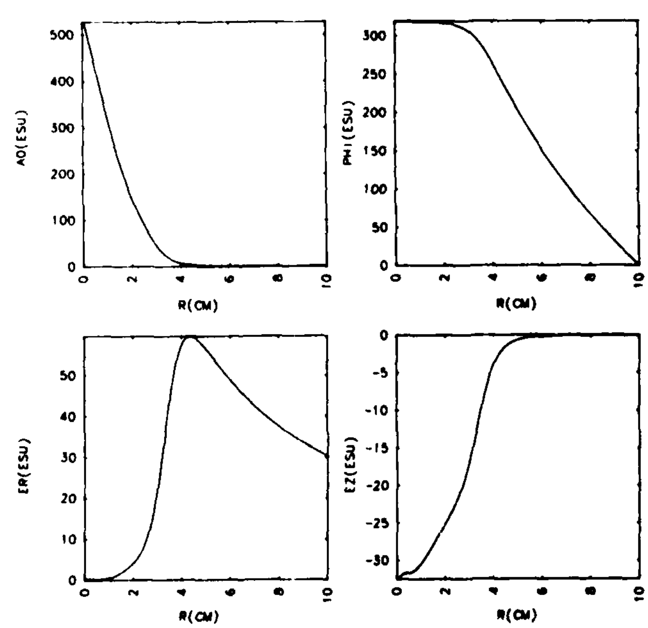

SNAPSHOT: X = 1.00, X STEP NO. 25
CASE: B FRAME: 2
J(ESU)
E+11
R(CM)
C/NU
NU
SIGMA
E+08
R(CM)


SNAPSHOT: X = 1.00, X STEP NO. 25
CASE: B FRAME: 3
AQ(ESU)
PHI(ESU)
ER(ESU)
EZ(ESU)
R(CM)

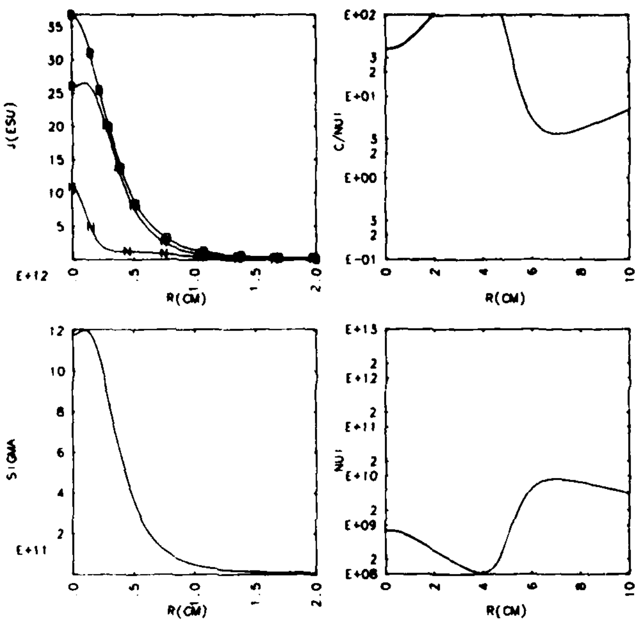
SNAPSHOT: X = 10.00, X STEP NO. 250 CASE: B FRAME: 4



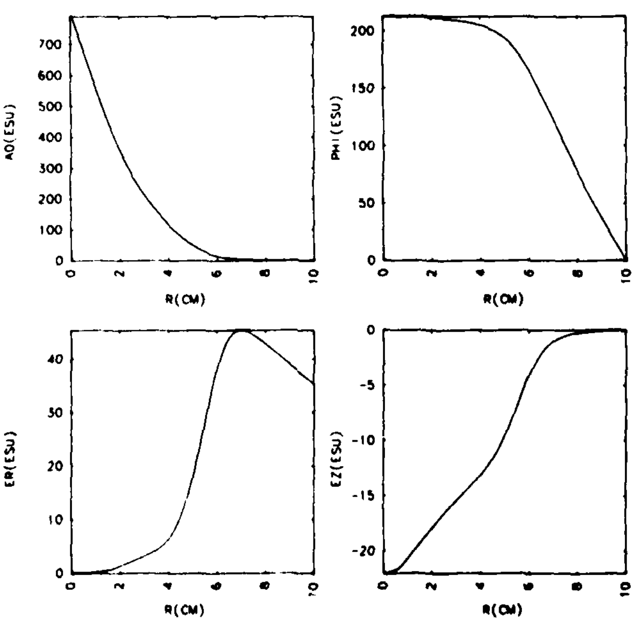
SNAPSHOT X = 10.00, X STEP NO 250 CASE: B FRAME: 5

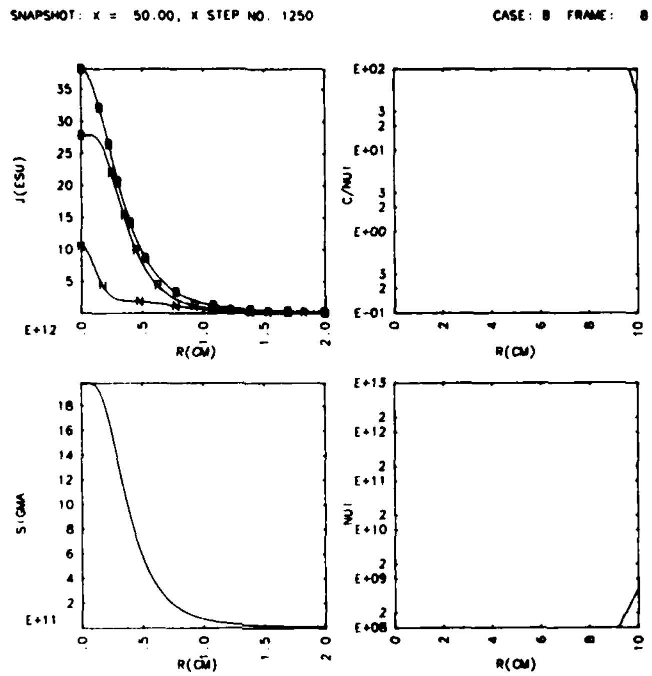


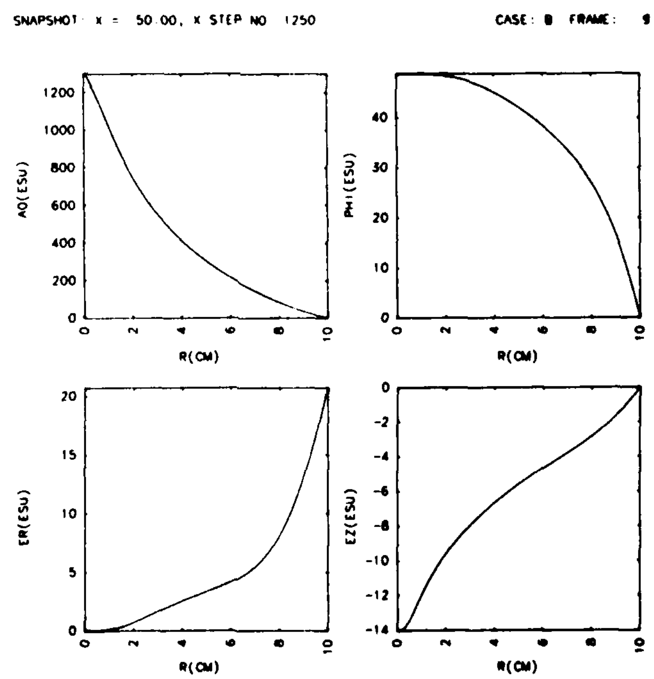
SNAPSHOT: X = 20.00, X STEP NO. 500 CASE: B FRAME: 6



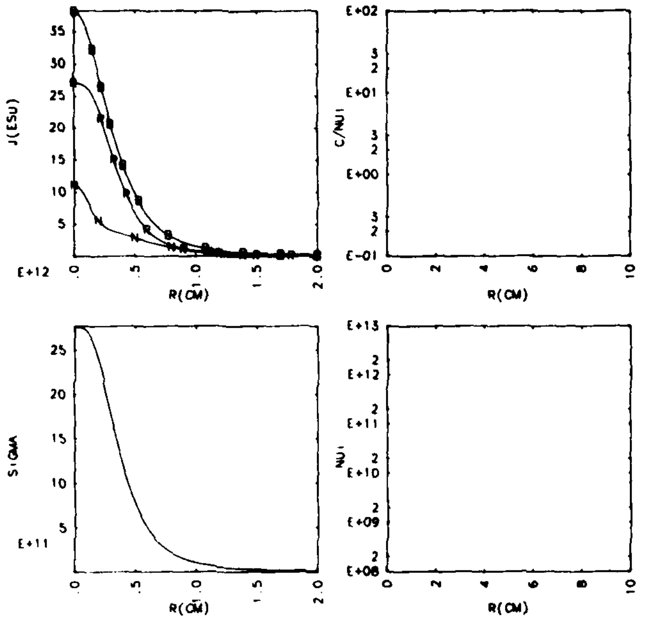
SNAPSHOT: X = 20.00, X STEP NO. 500 CASE: B FRAME: 7



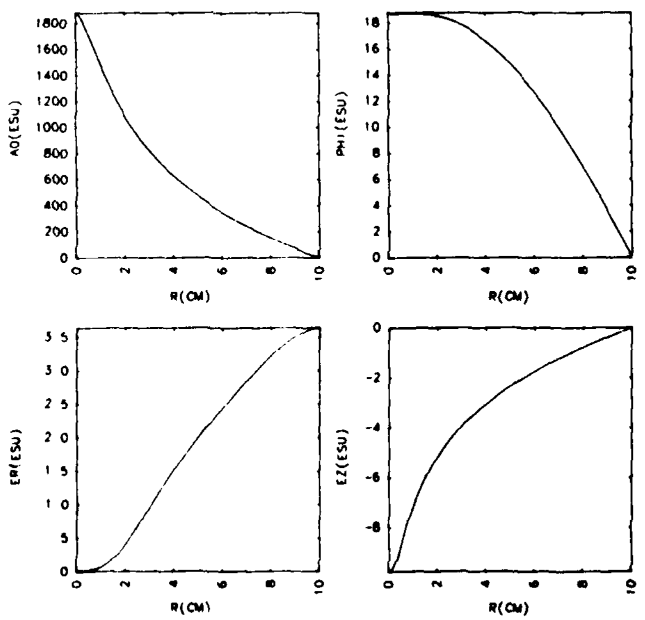

SNAPSHOT: X = 50.00, X STEP NO. 1250
CASE: B FRAME: 8
J(ESU)
E+12
R(CM)
C/NU1
E+02
E+01
E+00
E-01
SIGMA
E+11
NU1
E+13
E+12
E+11
E+10
E+09
E+08


SNAPSHOT: X = 50.00, X STEP NO. 1250
CASE: B FRAME: 9
AO(ESU)
PHI(ESU)
R(CM)
ER(ESU)
EZ(ESU)

SNAPSHOT: X = 100.00, X STEP NO. 2500 CASE: B FRAME: 10



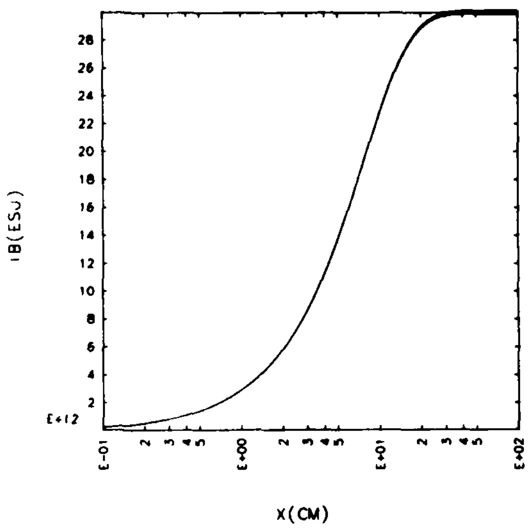
SNAPSHOT: X = 100.00, X STEP NO. 2500 CASE: B FRAME: 11



PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:52:50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

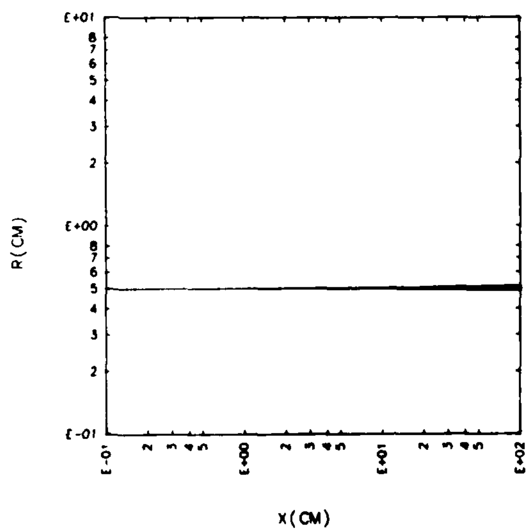


CASE: B FRAME: 12

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:52:50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

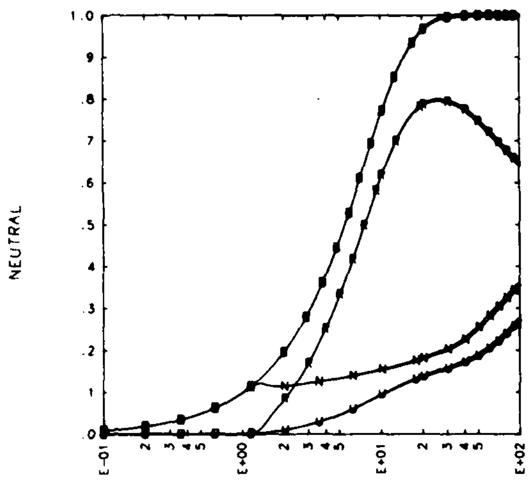


CASE B FRAME 13

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:52:50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

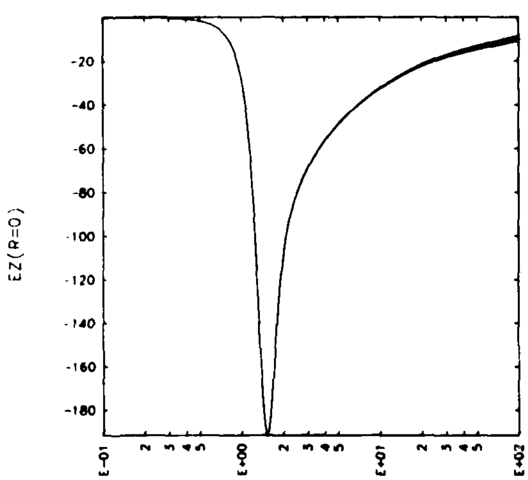


CASE: B FRAME: 14

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:52:50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

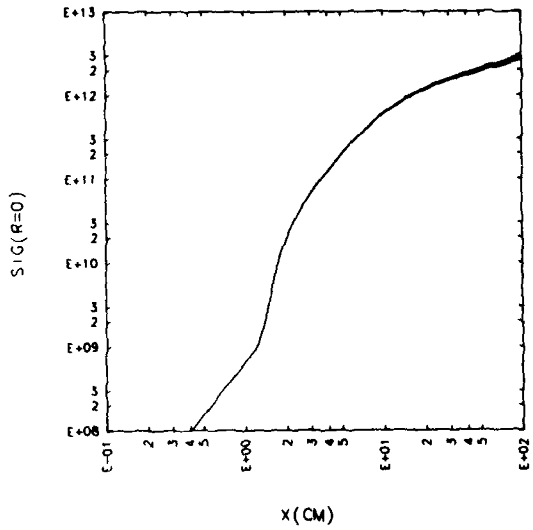


CASE: B FRAME: 15

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:52:50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

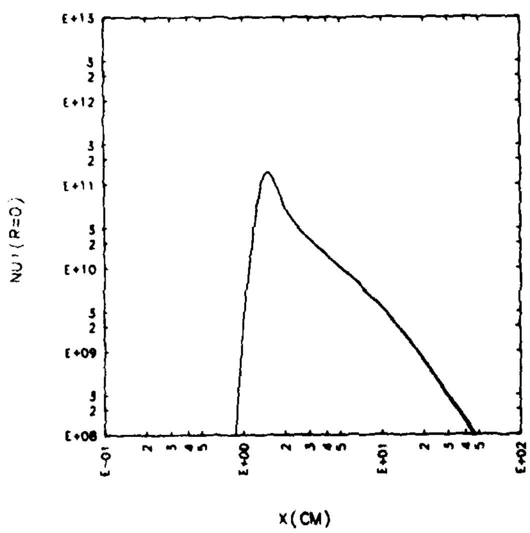


CASE: B FRAME: 16

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:52:50
09/22/81

IBEAM =
9.993E+03
LRISE =
1.000E+01
ROMIN =
5.000E-01
ROMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01



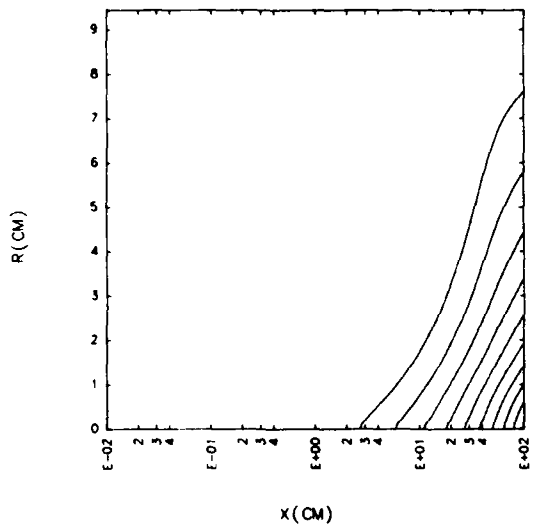
CASE B FRAME 17

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF AO(R,X)

TIME, DATE:
13:52:50
09/22/81
IBEAM =
9.993E+03
LRISE =
1.000E+01
RBMIN =
5.000E-01
RBMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

AO

C(1)= 1.863E+02
C(2)= 3.725E+02
C(3)= 5.588E+02
C(4)= 7.450E+02
C(5)= 9.313E+02
C(6)= 1.118E+03
C(7)= 1.304E+03
C(8)= 1.490E+03
C(9)= 1.676E+03
C(10)= 1.863E+03



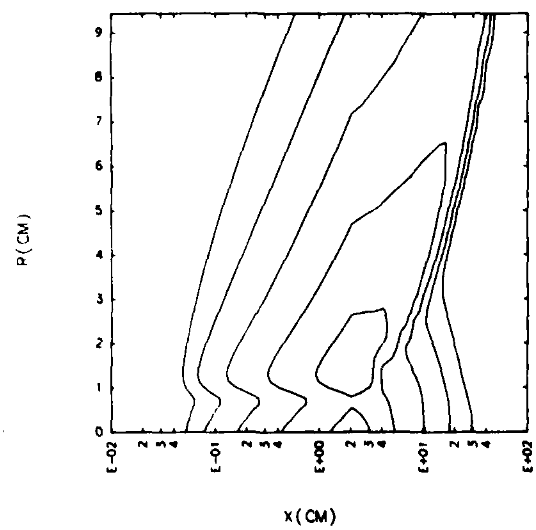
CASE: B FRAME: 18

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF NUSUBI(R,X)

TIME, DATE:
13:52:50
09/22/81
IBEAM =
9.993E+05
LRISE =
1.000E+01
RBMIN =
5.000E-01
RBMAX =
5.000E-01
XLOC =
1.500E+01
XWDTH =
1.500E+01

NUSUBI

C(1)= 3.162E+08
C(2)= 1.000E+09
C(3)= 3.162E+09
C(4)= 1.000E+10
C(5)= 3.162E+10
C(6)= 1.000E+11
C(7)= 3.162E+11
C(8)= 1.000E+12
C(9)= 3.162E+12
C(10)= 1.000E+13



CASE: B FRAME: 19

PHOENIX

BEAM PARAMETERS

IBO(AMPS)	= 1.000E+05	LR(CM)	= 3.000E+01
GAMMAO	= 1.000E+02	IPROFILE	= 2
ROMIN(CM)	= 2.000E-01	ROMAX(CM)	= 4.000E+01
XLOC(CM)	= 1.500E+01	XWDTH(CM)	= 1.500E+01
ISIGMOD	= 0		

GAS PARAMETERS

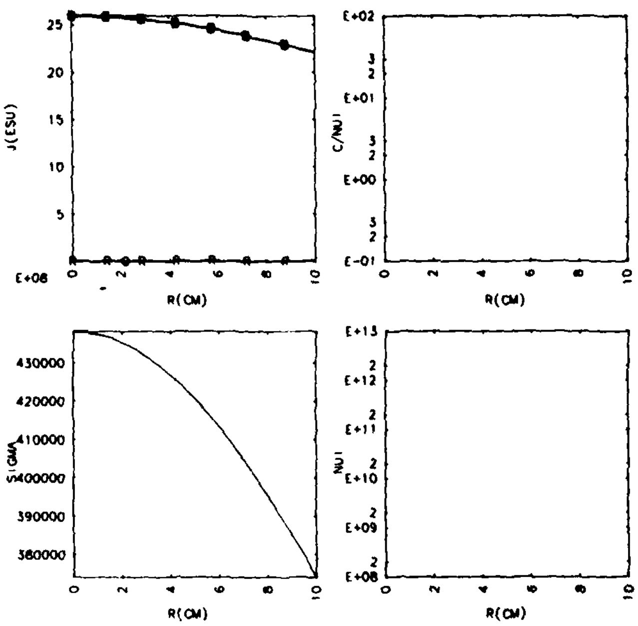
ENOO(CM**-3)	= 1.000E+04	KSCATTER	= 1.699E+03
KBEAM	= 6.690E+00	LAMBDARO	= 3.133E+04
IFRHOHAT	= 1	RHOHATO	= 1.000E+00

NUMERICAL PARAMETERS

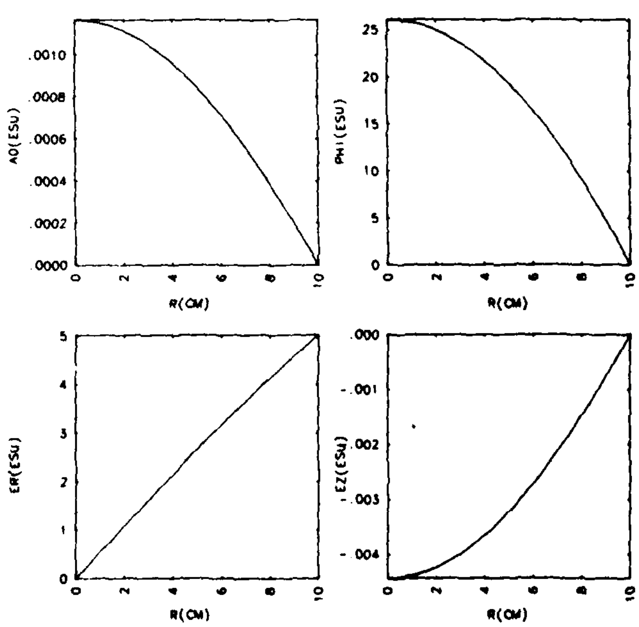
NR	= 220	B(CM)	= 1.000E+01
NRLNSTEP	= 40	RO(CM)	= 1.000E+00
RLNFAC	= 1.000E+00	NX	= 2500
NDX	= 1	DXVALUES(1) CM	= 4.000E-02

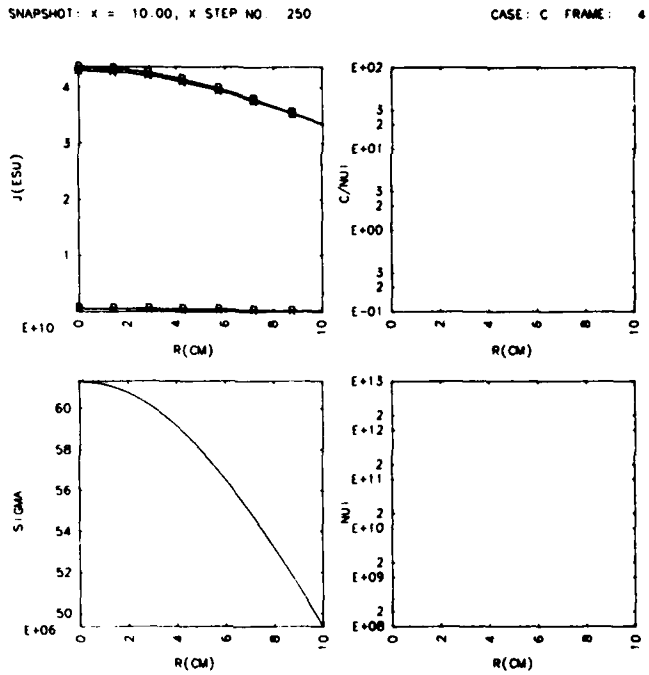
CASE: C FRAME: 1

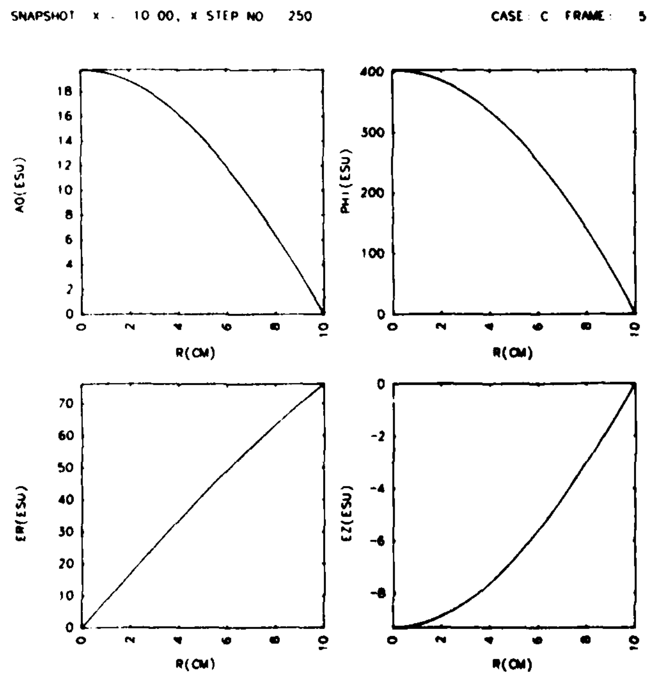
SNAPSHOT: X = 1.00, X STEP NO. 25 CASE: C FRAME: 2



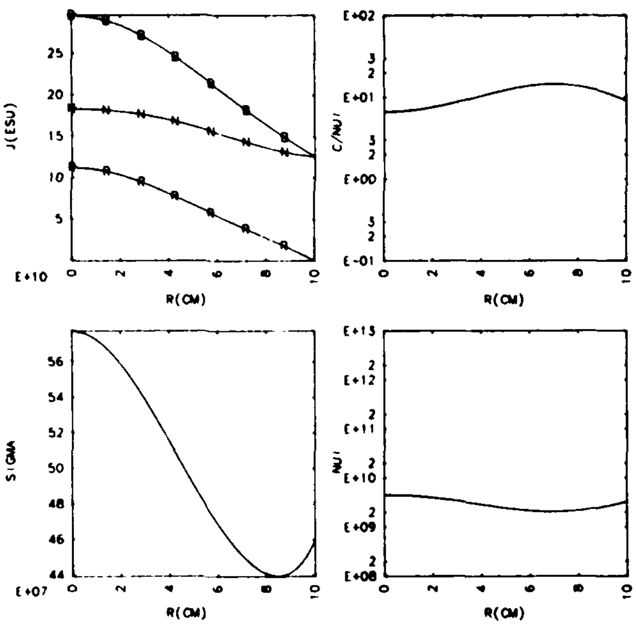
SNAPSHOT: X = 1.00, X STEP NO. 25 CASE: C FRAME: 3



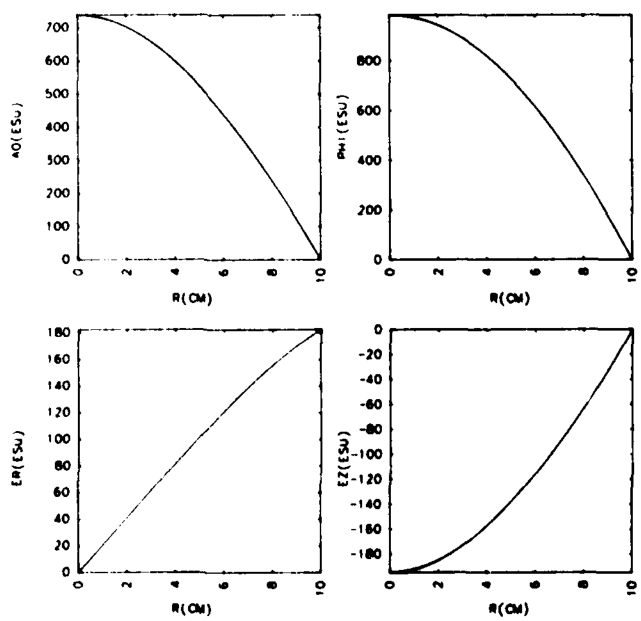

SNAPSHOT: X = 10.00, X STEP NO. 250
CASE: C FRAME: 4
J(ESU)
E+10
R(CM)
C/NU
E+02
E+01
E+00
E-01
SIGMA
E+06
NU
E+13
E+12
E+11
E+10
E+09
E+08


SNAPSHOT X = 10.00, X STEP NO 250
CASE: C FRAME: 5
AQ(ESU)
PHI(ESU)
ER(ESU)
EZ(ESU)
R(CM)

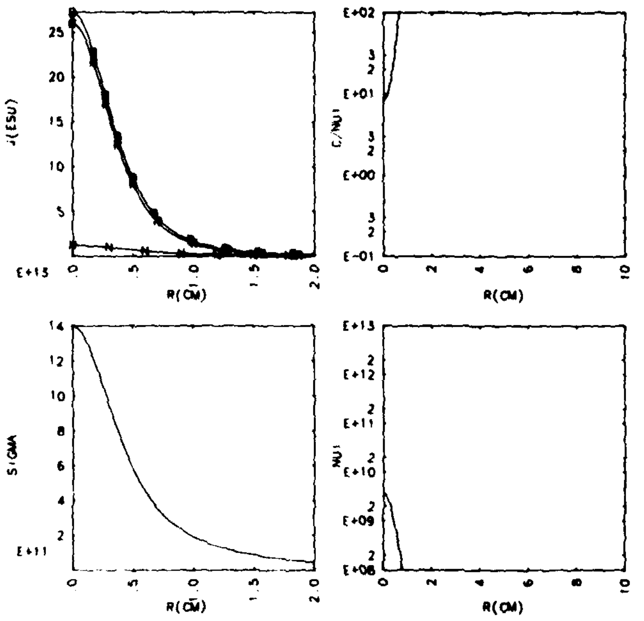
SNAPSHOT: X = 20.00, X STEP NO. 500 CASE: C FRAME: 6



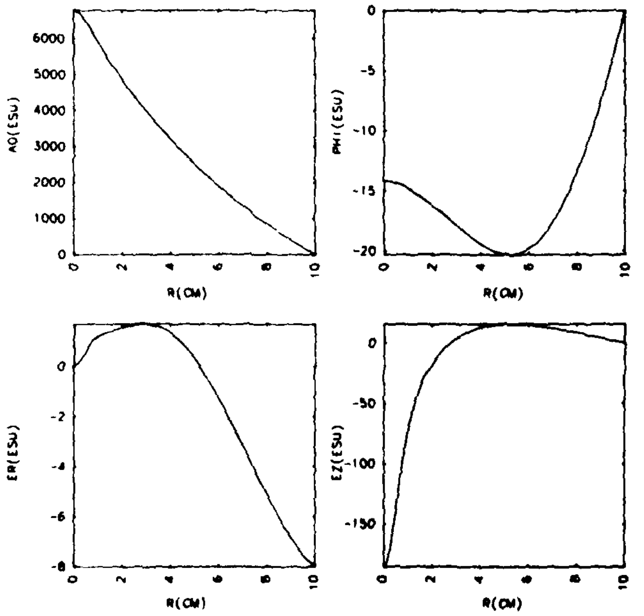
SNAPSHOT X = 20.00, X STEP NO 500 CASE: C FRAME: 7



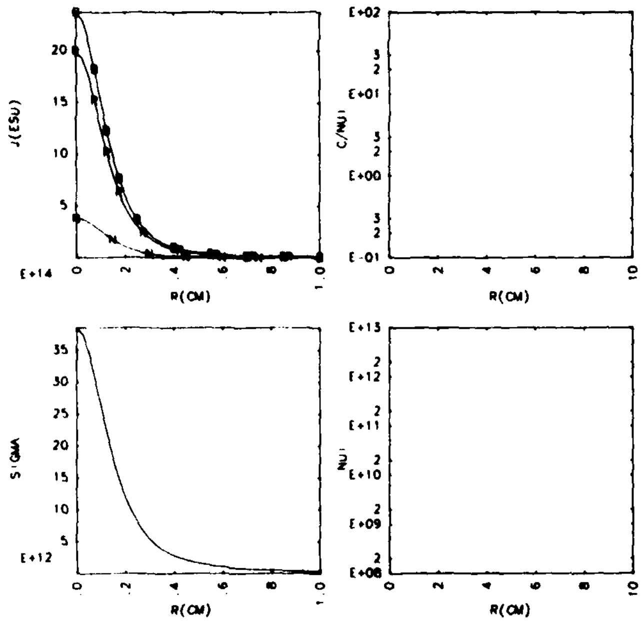
SNAPSHOT: X = 50.00, X STEP NO. 1250 CASE: C FRAME: 8



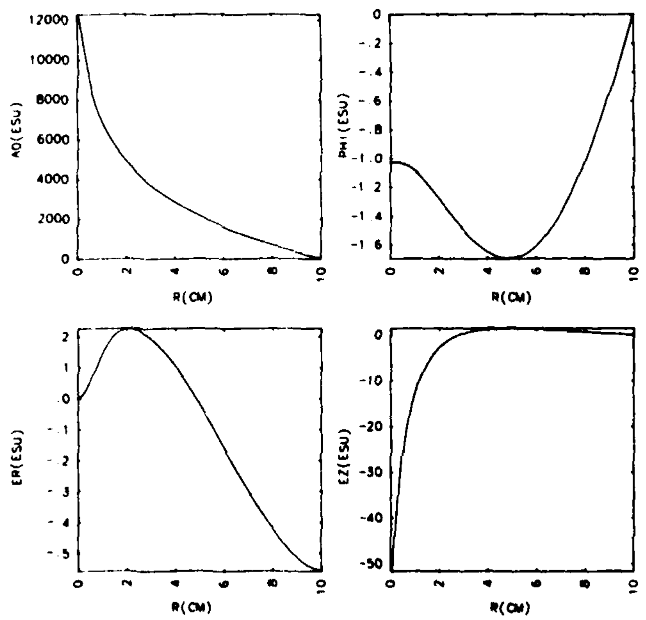
SNAPSHOT: X = 50.00, X STEP NO. 1250 CASE: C FRAME: 9



SNAPSHOT: x = 100.00, X STEP NO. 2500 CASE: C FRAME: 10



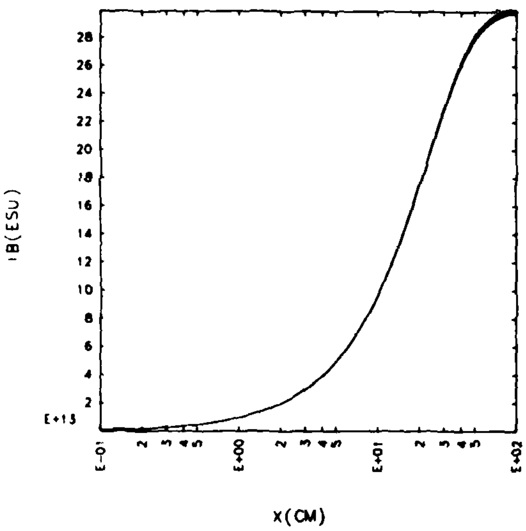
SNAPSHOT: x = 100.00, X STEP NO. 2500 CASE: C FRAME: 11



PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
13:57:15
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
2.000E-01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWDTH =
1.500E+01

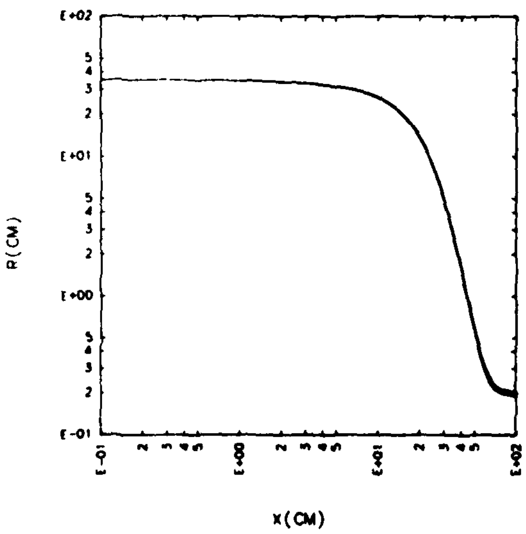


CASE C FRAME 12

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:57:15
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
2.000E-01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWDTH =
1.500E+01

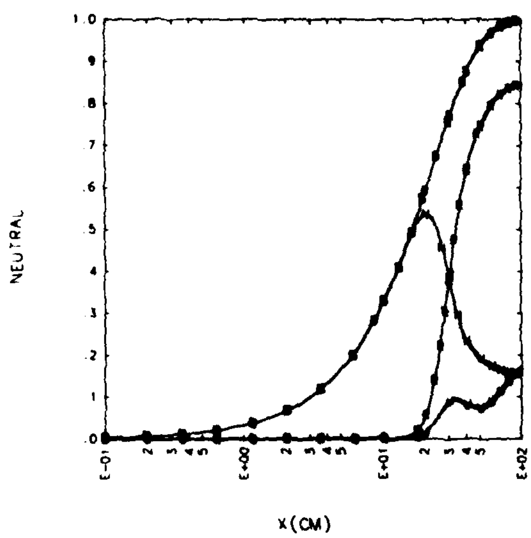


CASE C FRAME 13

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:57:15
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
2.000E-01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWDTH =
1.500E+01

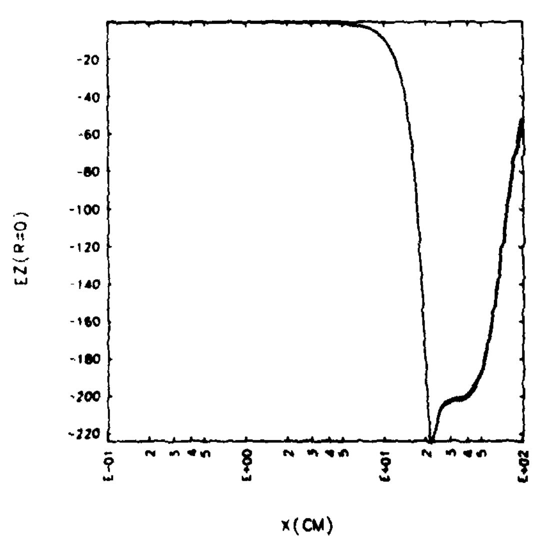


CASE C FRAME 14

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:57:15
09/22/81

IBEAM
9.993E+04
LRISE
3.000E+01
ROMIN =
2.000E-01
ROMAX
4.000E+01
XLOC =
1.500E+01
XWDTH =
1.500E+01

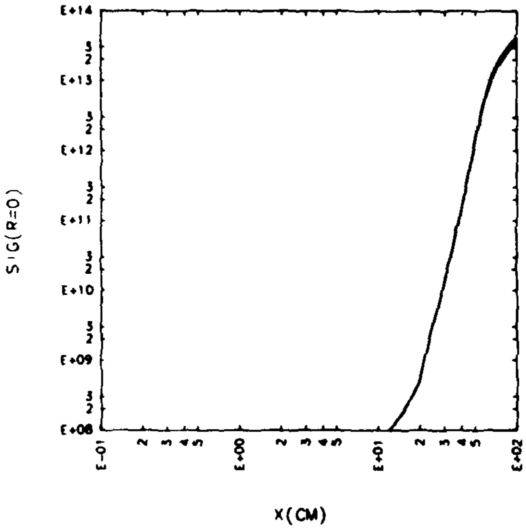


CASE C FRAME 15

PHOENIX   FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
13:57:15
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
2.000E-01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWDTH =
1.500E+01

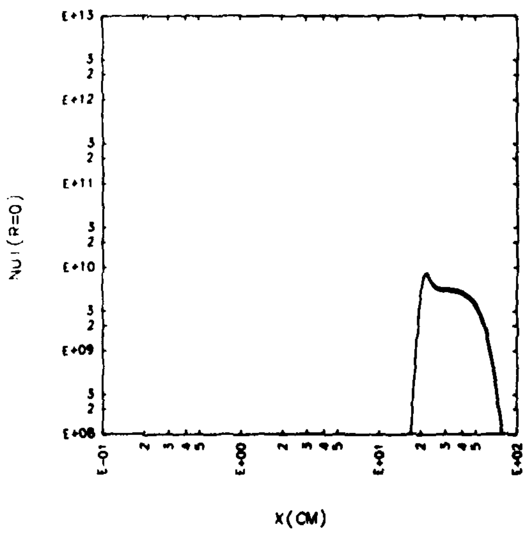


CASE C FRAME 16

PHOENIX   FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

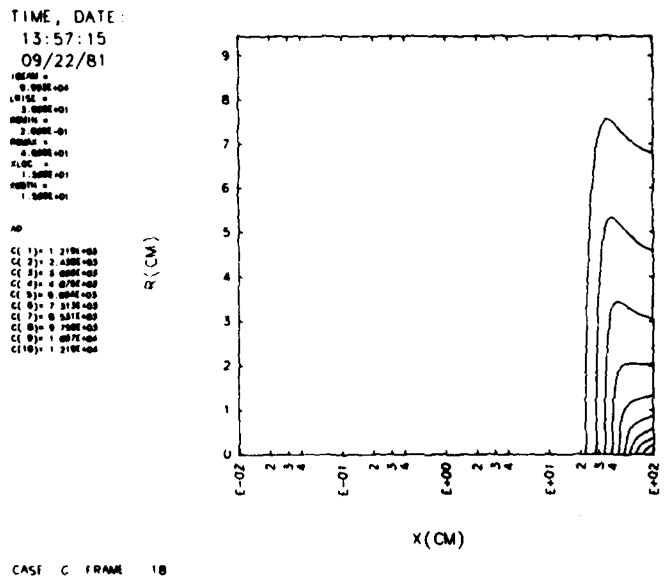
TIME, DATE
13:57:15
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
2.000E-01
ROMAX =
4.000E+01
XLOC =
1.500E+01
XWDTH =
1.500E+01

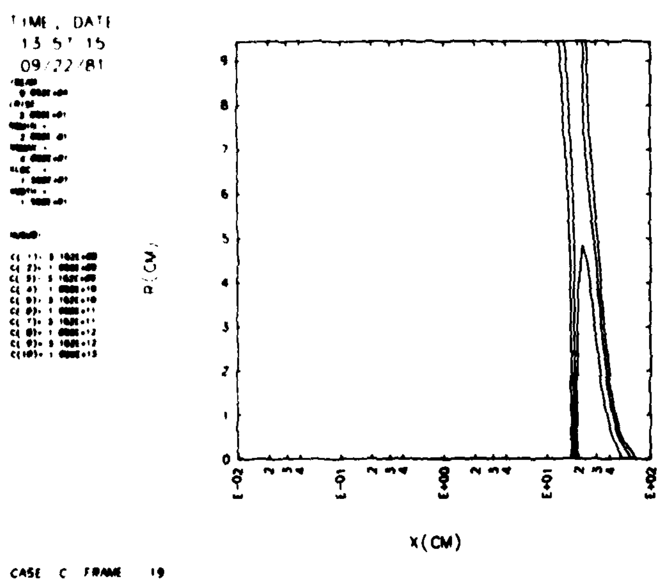


CASE C FRAME 17

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF A0(R,X)



PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF NUSUBI(R,X)



PHOENIX

BEAM PARAMETERS

IBO(AMPS)	= 1.000E+05	LR(CM)	= 3.000E+01
GAMMAO	= 1.000E+02	IPROFILE	= 2
ROMIN(CM)	= 5.000E-01	ROMAX(CM)	= 1.000E+02
XLOC(CM)	= 2.000E+01	XWDTH(CM)	= 1.800E+01
ISIGMOD	= 0		

GAS PARAMETERS

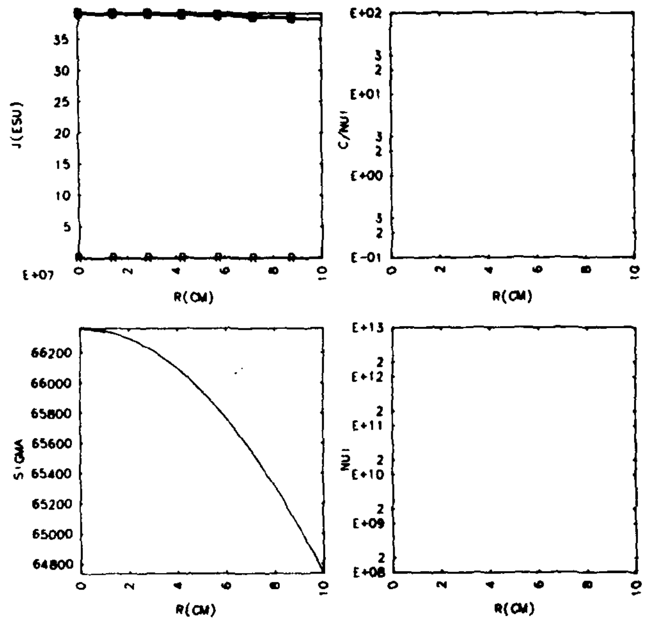
ENOO(CM**-3)	= 1.000E+04	KSCATTER	= 1.699E+03
KBEAM	= 6.690E+00	LAMBDARO	= 3.133E+04
IFRHOHAT	= 1	RHOHATO	= 1.000E+00

NUMERICAL PARAMETERS

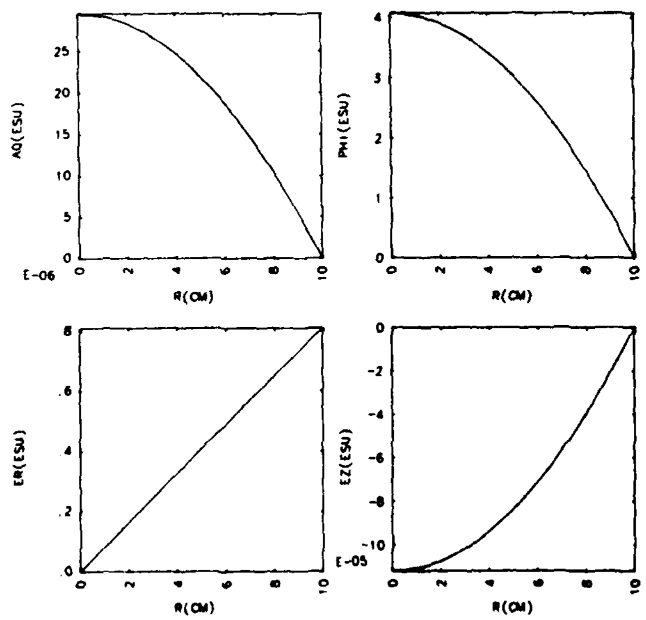
NR	= 220	B(CM)	= 1.000E+01
NRLNSTEP	= 40	RO(CM)	= 1.000E+00
RLNFAC	= 1.000E+00	NX	= 2500
NDX	= 1	DXVALUES(1) CM	= 4.000E-02

CASE: D FRAME: 1

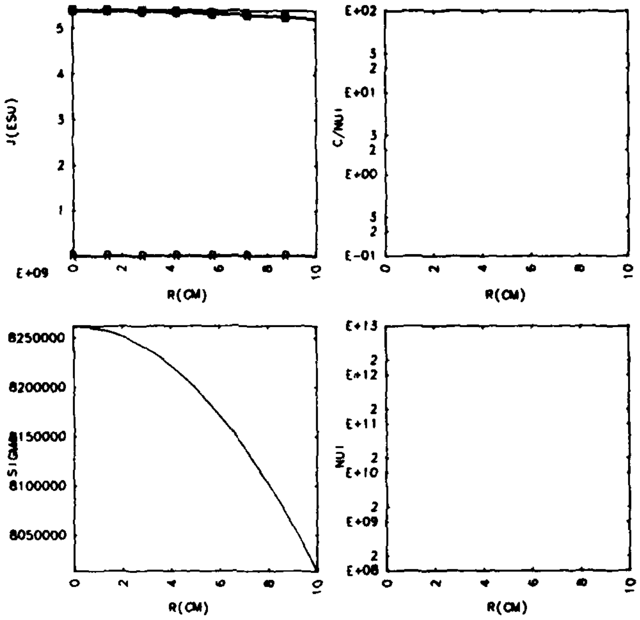
SNAPSHOT: X = 1.00, X STEP NO. 25 CASE: D FRAME: 2



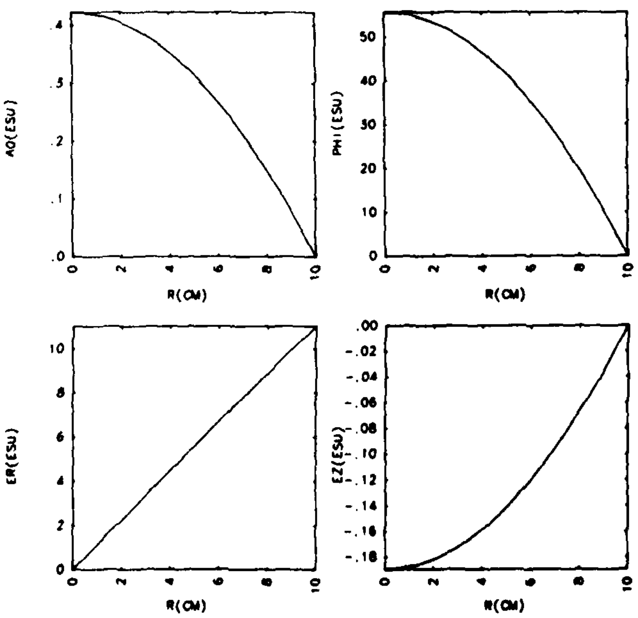
SNAPSHOT: X = 1.00, X STEP NO. 25 CASE: D FRAME: 3



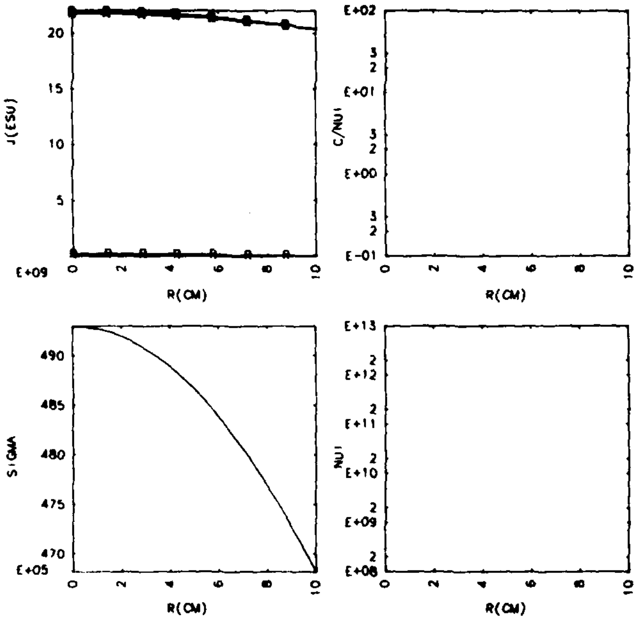
SNAPSHOT: X = 10.00, X STEP NO. 250 CASE: D FRAME: 4



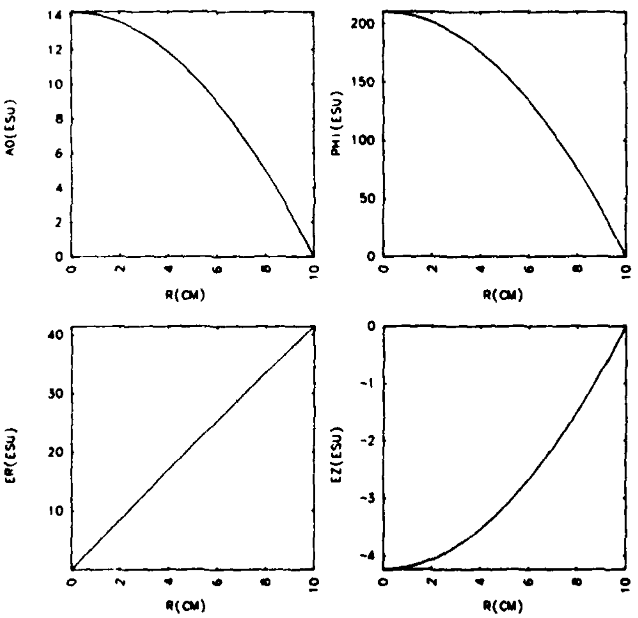
SNAPSHOT X = 10.00, X STEP NO. 250 CASE: D FRAME: 5



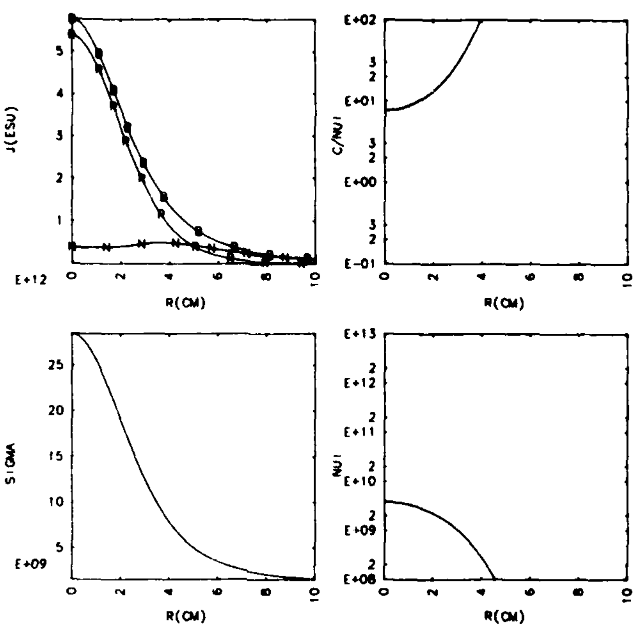
SNAPSHOT: X = 20.00, X STEP NO. 500 CASE: D FRAME: 6



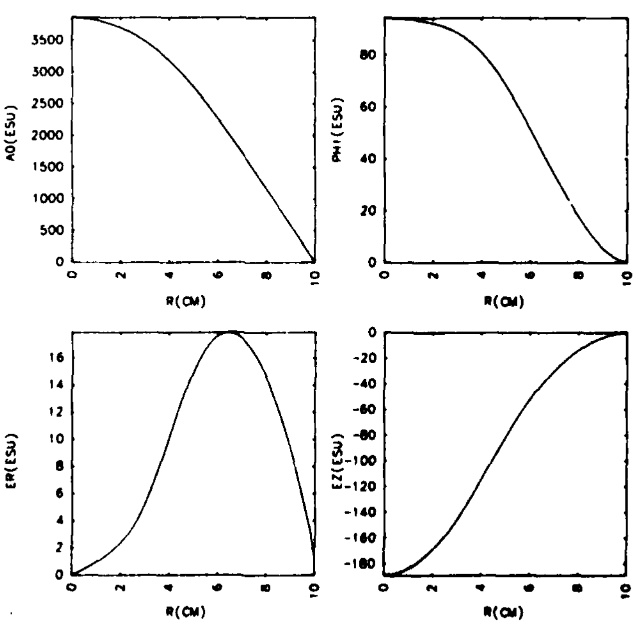
SNAPSHOT X = 20.00, X STEP NO. 500 CASE: D FRAME: 7



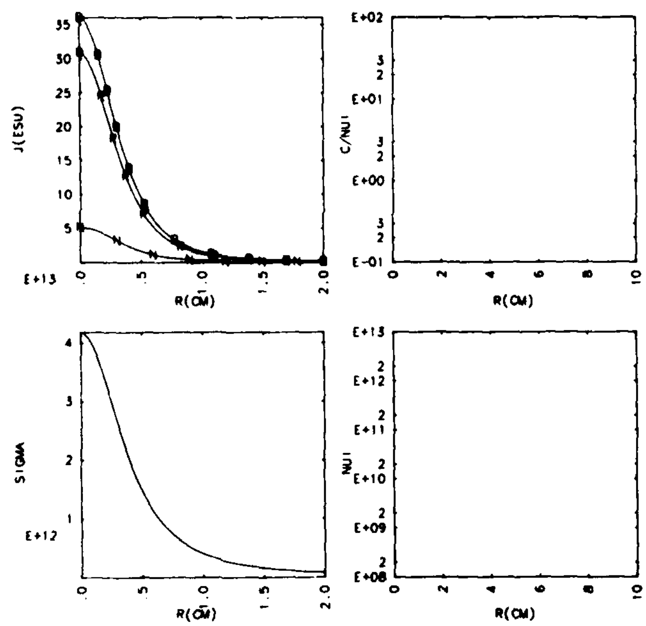
SNAPSHOT X = 50.00, X STEP NO. 1250 CASE: D FRAME: 8



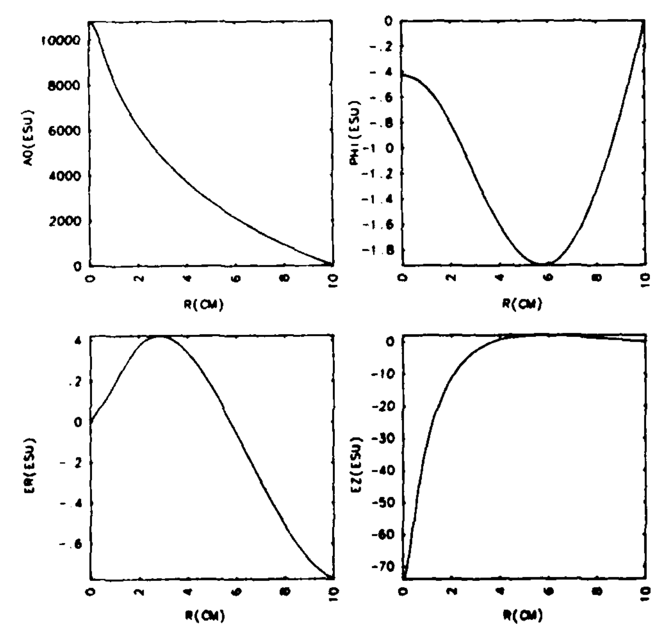
SNAPSHOT X = 50.00, X STEP NO. 1250 CASE: D FRAME: 9



SNAPSHOT: X = 100.00, X STEP NO 2500 CASE: D FRAME: 10



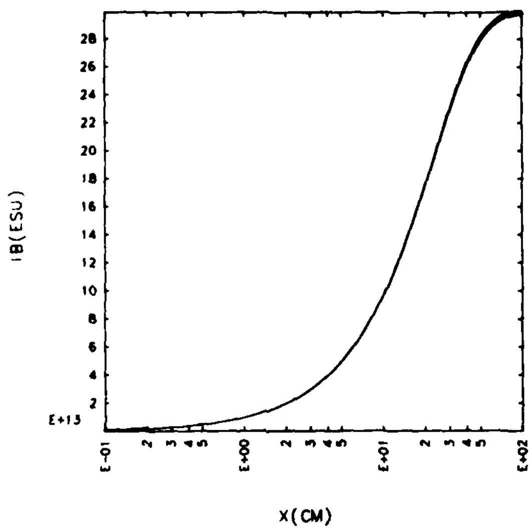
SNAPSHOT X = 100.00, X STEP NO 2500 CASE: D FRAME: 11



PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
14:04:23
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
5.000E-01
ROMAX =
1.000E+02
XLOC =
2.000E+01
XWDTH =
1.800E+01

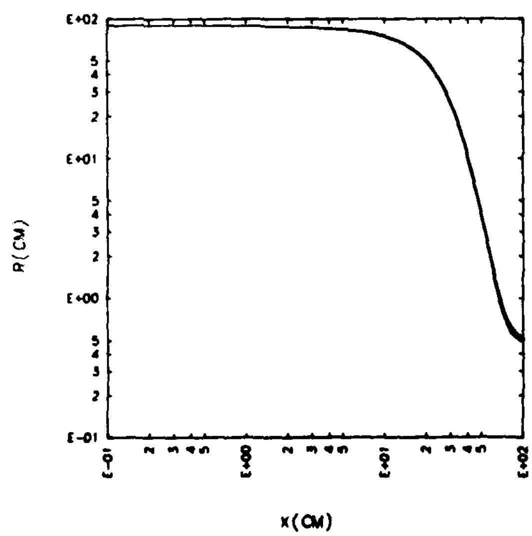


CASE: D FRAME: 12

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE
14:04:23
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
5.000E-01
ROMAX =
1.000E+02
XLOC =
2.000E+01
XWDTH =
1.800E+01

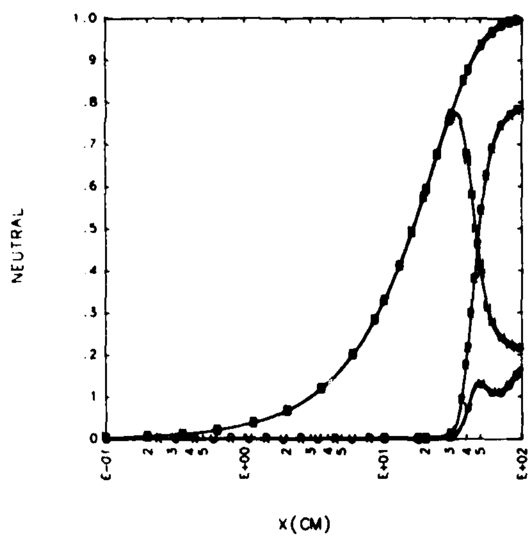


CASE D FRAME 13

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
14:04:23
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
5.000E-01
ROMAX =
1.000E+02
XLOC =
2.000E+01
XWDTH =
1.800E+01

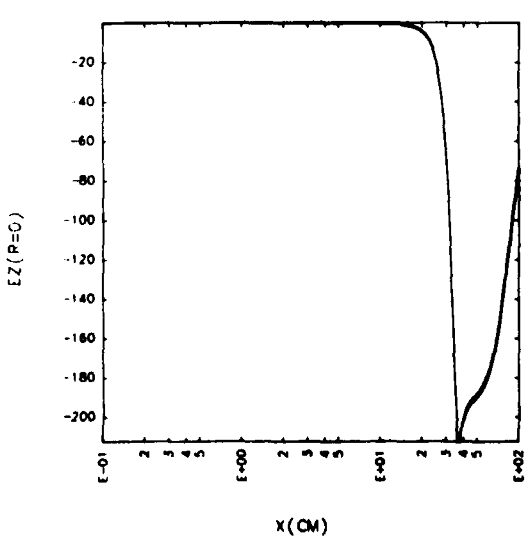


CASE: D FRAME: 14

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
14:04:23
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
5.000E-01
ROMAX =
1.000E+02
XLOC =
2.000E+01
XWDTH =
1.800E+01

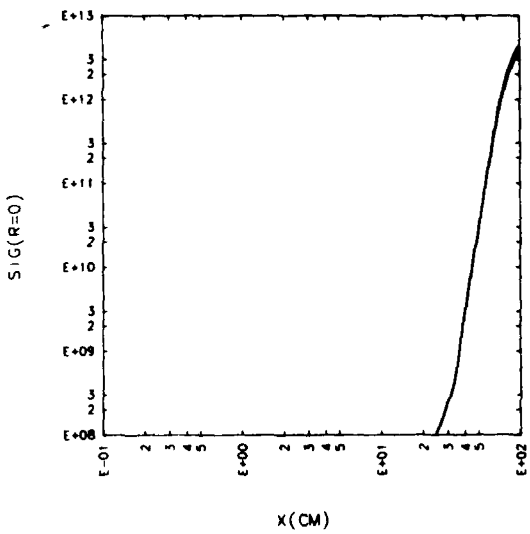


CASE D FRAME 15

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
14:04:23
09/22/81

IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
5.000E-01
ROMAX =
1.000E+02
XLOC =
2.000E+01
XWDTH =
1.800E+01

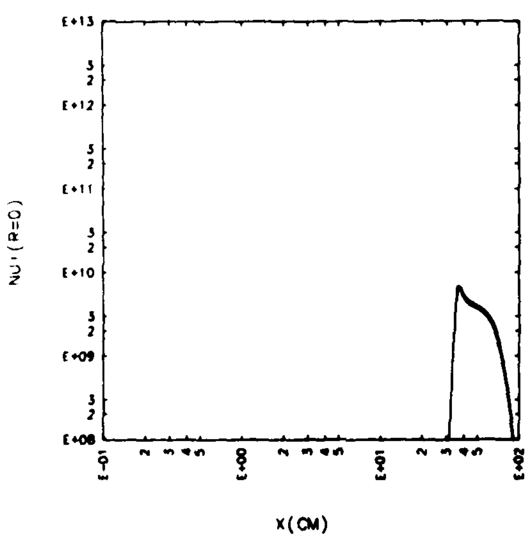


CASE: D FRAME: 16

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
PLOT VERSUS X

TIME, DATE:
14:04:23
09/22/81

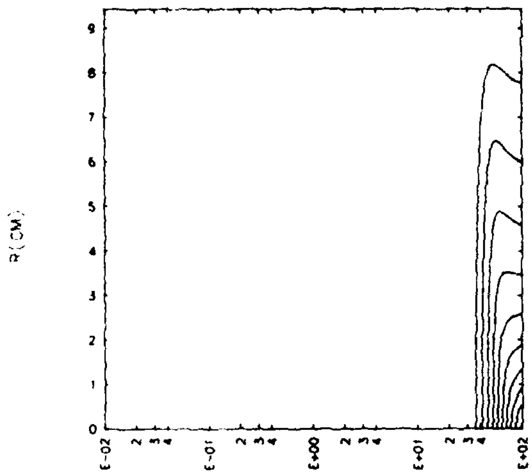
IBEAM =
9.993E+04
LRISE =
3.000E+01
ROMIN =
5.000E-01
ROMAX =
1.000E+02
XLOC =
2.000E+01
XWDTH =
1.800E+01



CASE: D FRAME: 17

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF AO(R,X)

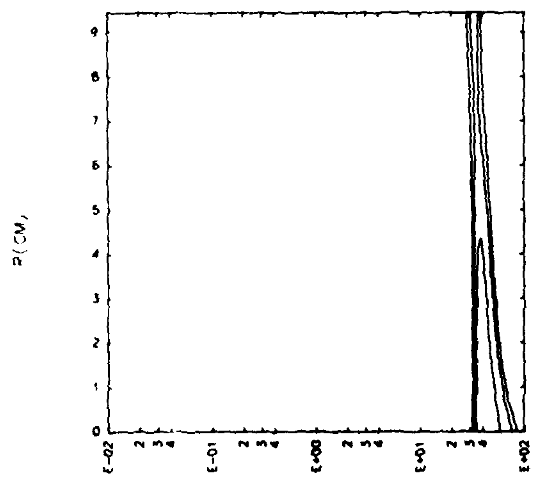
TIME, DATE
14:04:23
09/22/81



CASE 0 FRAME 18

PHOENIX FIELDSOLVER WITH FIXED JB(R,X)
CONTOUR PLOT OF NUSUBI(R,X)

TIME, DATE
14:04:23
09/22/81



CASE 0 FRAME 19

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